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No. II ✓

1897 ✓

THE JOURNAL
OF THE
IRON AND STEEL INSTITUTE

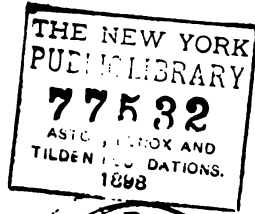
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EDITED BY
BENNETT H. BROUGH
SECRETARY

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THE
IRON AND STEEL INSTITUTE.

SECTION I.
MINUTES OF PROCEEDINGS.

CARDIFF MEETING.

THE AUTUMN MEETING of the IRON AND STEEL INSTITUTE was held at the South Wales Institution of Engineers on Tuesday, August 3, 1897—Mr. EDWARD P. MARTIN, President, in the chair.

THE MAYOR of CARDIFF (Alderman E. BEAVAN, J.P.), in gracefully welcoming the Institute to Cardiff, said he was sure that all would agree with him when he told them that it was not always that the Chief Magistrate of a town had such an agreeable and pleasant duty to perform as had fallen to his lot that morning. When he looked around that large assembly, and considered the genial and beautiful weather they were having, he was delighted to have the opportunity under such excellent and distinguished circumstances of welcoming the Iron and Steel Institute to the great and growing town of Cardiff. He remembered that the Institute had visited many of the largest towns and cities of the United Kingdom; he also remembered that they had visited Continental countries, and had, once at least, visited the great city of New York; and though a great deal might be said for an Institute when it could spread its wings over half or more of the entire globe, he wished to say to them, in the name of Cardiff, its inhabitants, the Corporation
1897.—ii.

and himself, that wherever they had been, and under however favourable circumstances they had met heretofore, in no place would they find a more cordial, hearty, and enthusiastic welcome than in that town. It was a special privilege, and he felt it to be a great honour, that he happened to be Mayor and Chief Magistrate of the town on the occasion of their visit; and bearing in mind his pleasant recollections of being with them in London in May last, and also attending the dinner at the Hotel Cecil on that occasion, he was specially proud now to welcome them to the little town (compared with London) of Cardiff. He was sure they would need no words of his to make them feel comfortable in relation both to the reception they would have in a general sense, to the hospitality that would be shown to them, and the consideration they would receive while they were engaged in the meetings during the week. They had only to read the local papers, and to see set out in detail the programme of the week's proceedings, and to reckon up the number of lunches, dinners, suppers, &c., &c., in order, as far as those "good creatures" went, to insure satisfaction to every member of the Iron and Steel Institute. But that perhaps was more humorous than anything else. What he wanted to say more especially was that Cardiff looked upon the Iron and Steel Institute as a great and mighty Institution, not only achieving noble objects in connection with its own technical workings, but spreading the benefits of its science and its knowledge throughout the length and breadth of the country and the entire civilised world. When a body of gentlemen such as he saw before him that morning could come to Cardiff and devote the whole week to the furtherance of commerce and commercial enterprise in connection with coal, iron, and steel, he thought it spoke well for the country, and he was sure they ought to and must feel deeply indebted to the members of the Iron and Steel Institute for selecting Cardiff in which to hold their annual meeting.

In another place a few moments before he had spoken to the President, and tried to impress upon his mind the fact that they were very much indebted to him and to some few others—but mainly, perhaps, to the President—for the selection of Cardiff. He wished to give the President that credit, and to assure him and

the members, of Cardiff's obligation to the Institute for coming amongst them. He trusted the members would have a very pleasant, enjoyable, and profitable time. After all, Cardiff was not the one-eyed place that some people said it was. He need not expatiate upon that, for they had already been there a day or so, and would be able to verify what he had said, at any rate in that respect. They had beautiful walks, beautiful suburbs, and beautiful parks, and they were a good-looking race of people; and he ventured to think that when the programme was read, the members would believe him when he said that the opening that morning augured well for a very comfortable, enjoyable, and most successful week. He did not know that he should so much care to see them next Friday night, because he was afraid that some of them would be saying, "Well, I am so tired; I have been knocking about so much this week and engaged in so many things, that I am almost glad to go home." He would urge upon them not to get tired at the beginning. If they proceeded with their work and did their duty, as he was sure they would do, abundant success would crown the labours of the autumnal meetings. In conclusion, he was very glad indeed to have the special pleasure of attending that morning to heartily welcome the members to Cardiff, and to wish them and the Institute lasting and continued prosperity.

The PRESIDENT said he envied the facility and eloquence with which the Mayor had so kindly received the members of the Institute; but though his words might fail to express all he wished to say, his feelings were none the less deep on that account. On behalf of the Institute he begged to thank the Mayor, and Sir William Lewis and the Local Reception Committee, for the very kind welcome that had been accorded to them. It was now some twenty-seven years since the Iron and Steel Institute had visited that district. Since that time the town of Cardiff—which then occupied an almost secondary position—had advanced by leaps and bounds, until it now stood quite in the forefront of the world as regarded its position as a port. The "little town" of Cardiff might stand comparison with even the city of London, for in 1896 the foreign clearances of the port of Cardiff exceeded those of London by half a million

tons ; while New York stood third on the list. Some one had called Cardiff the Chicago of the West, and their hope was that it might continue to increase and prosper in the future as it had done in the past. Again he thanked the Mayor on behalf of the Iron and Steel Institute for the kind and gracious welcome that had been accorded to them, and trusted that the clerk of the weather might prove as gracious, and so enable them to enjoy the great hospitality that had been offered to them.

Sir WILLIAM THOMAS LEWIS, Bart., as chairman of the Local Committee, begged leave to thank the Mayor most sincerely for his kindness in attending and so cordially welcoming the members of the Iron and Steel Institute.

The MAYOR OF CARDIFF said he was exceedingly obliged for the very kind words that had fallen from the lips of the President and Sir William Thomas Lewis in connection with himself. He could only repeat what he had said before, that it afforded him the greatest pleasure to welcome the members in the manner he had done in the name of the town and Corporation of Cardiff. The President had referred to the position of Cardiff as a port, and perhaps he might be allowed to remind the members that the port of Cardiff exported about sixteen million tons of coal a year. It was not, therefore, so small a place as he was sorry to say some people seemed to think. Even the press were getting enlightened in relation to the great importance of Cardiff. It took them a long time to wake up, but they were now pretty much alive to the fact that the town was of "considerable importance." With the aid of the Iron and Steel Institute in connection with the present meetings, and in connection with its general work and operations, he was sure the town would soon become of still greater importance. He thanked the Institute very heartily, and hoped to have the pleasure and honour of seeing the members at the Mayoress's and his own reception, to which they had all received invitations.

The SECRETARY read the minutes of the last meeting, which were confirmed and signed by the President.

The SECRETARY read the following address, which had been sent to Her Majesty the Queen on June 22nd :—

To Her Most Gracious Majesty the Queen.

MAY IT PLEASE YOUR MAJESTY,

We, the President, Council, and Members of the Iron and Steel Institute, humbly desire to be permitted to convey to your Majesty our earnest and most respectful congratulations upon the attainment of the sixtieth year of your Majesty's reign, a reign which is conspicuous for the progress made in the Metallurgical Arts, for the promotion of which this Society was founded.

The greatest inventions bearing on the manufacture of iron and steel have originated in Great Britain, and we attribute this to the beneficent Government which has there been enjoyed, and to the fact that the Throne has been occupied by one so wise and prudent as your Majesty.

We earnestly pray that your Majesty may long be spared to rule over this vast Empire.

Signed on behalf of the Iron and Steel Institute,

EDWARD P. MARTIN,
President.

BENNETT H. BROUGH,
Secretary.

LONDON, June 22, 1897.

The PRESIDENT called upon the Secretary to announce the names of the officers who retired by rotation in May next.

The SECRETARY said that in accordance with Rule 10 it had to be announced that the members who retired by rotation in May next were :—

Vice-Presidents.

W. H. Bleckly.	A. Carnegie.
A. Keen.	

Members of Council.

David Evans.	Victor Cavendish.
Arthur Cooper.	William Evans.
A. T. Walker.	

All these gentlemen, both Vice-Presidents and Members of Council, were eligible for re-election. It was competent for

members to nominate candidates for office up to one month previous to the general meeting.

Mr. T. ASHBURY and Mr. A. P. HEAD were appointed Scrutineers, and on the completion of their scrutiny reported that the following gentlemen had been duly elected members of the Institute:—

NAME.	ADDRESS.	PROPOSERS.
Andrews, Thomas . .	Chelmsford, Newport Road, Cardiff	Thomas Morel, Edw. P. Martin, Samuel Gething Lewis.
Bailey, Thomas Henry, M. Inst. C.E.	98 St. Mary Street, Cardiff	Sir William T. Lewis, Arthur Keen, Edw. P. Martin.
Bannister, Alfred . .	Kirkstall Forge, Leeds	Arthur Cooper, Edmund Butler, B. F. Butler.
Bertrand, Ernst . . .	Eisenwerk, Kladno, Austria	Karl Wittgenstein, Arthur Cooper, Percy C. Gilchrist.
Bird, Clarence . . .	2 Laurence Pountney Hill, London, E.C.	E. Windsor Richards, Berkeley Paget, James J. Wallis.
Blackwell, George Grove	The Albany, Liverpool	F. Monks, Jacob Higson, John Pattinson.
Blenkinsop, George Henry	Melbourne Place, Swansea	W. H. Powell, William Darby, Isaac Butler.
Bonvillain, Philibert .	6 Rue Blanche, Paris	A. Tannett Walker, J. Ros-siter Hoyle, Alexander Anderson.
Booth, Arthur . . .	Union Foundry and Iron Works, Rodley, Leeds	John Wm. Booth, A. T. Walker, T. P. Reay.
Brown, William Pater-son	Bay View, Millom, Cumberland	John Crum, William Mc-Cowan, George J. Snelus.
Campbell, James . .	Iron Works, Millom, Cumberland	John Crum, William Mc-Cowan, George J. Snelus.
Chandler, Lincoln . .	Patent Shaft and Axle-tree Company, Ltd., Wednesbury	Claud T. Cayley, George Flett, Enoch James.
Clarke, James Crawford	427 Glossop Road, Sheffield	Sydney J. Robinson, R. A. Hadfield, Joseph S. Beckett.
Cottam, Edwin . . .	Bute Steel and Spring Works, East Moors, Cardiff	Edw. P. Martin, J. J. Pick-ford, A. Bowen.
Cradock, Percy Stanley	Westfield House, Wakefield	J. E. Stead, H. Herbert Andrew, F. H. Wigham.
Darby, William . .	40 Calthorpe Road, Birmingham	J. E. Stead, Arthur Cooper, John H. Darby.
Daw, Frederic Weldon	Ebbw Vale, Mon.	W. H. Powell, Edwin Carlisle, Edward Riley.
Deacon, Maurice, M. Inst. C.E.	Sheepbridge Coal and Iron Co., Chesterfield	David Evans (Middles-brough), A. T. Walker, W. W. Clayton.
Dixon, Walter . . .	164 St. Vincent Street, Glasgow	James Riley, T. B. Rogerson, Fred. W. Paul.

ELECTION OF MEMBERS.

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NAME.	ADDRESS.	PROPOSERS.
Evans, David . . .	Carlton Villa, Oxford Street, Sheffield	Thomas Davage, Harry Marsden, Charles A. Winder.
Evans, David Llewellyn, F.G.S.	5 Bute Crescent, Cardiff	Edw. P. Martin, Christmas Evans, Benjamin Jones.
Haslam, Sir Alfred Seale	Derby	Sir William T. Lewis, Edward P. Martin, David Evans (Middlesbrough).
Herbert, Charles . .	Landore, Swansea	George Senior, Albert Senior, J. Rossiter Hoyle.
Hiraoka, Hiroshi . .	Hiraoka Iron Works, Tokio, Japan	George Cawley, William Gowland, Edw. P. Martin.
Hutchinson, John . .	Pentwyn House, Ebbw Vale, Mon.	Sir David Dale, Edw. P. Martin, William Whitwell.
I'Anson, Joseph Coventry	Palace Chambers, 9 Bridge Street, Westminster	William Whitwell, C. Arthur Head, James I'Anson.
John, Edward Thomas	Llwyn Onn, Grove Hill, Middlesbrough	Edw. P. Martin, David Evans, J. E. Stead.
Johnson, Guy R. . .	Embreville Blast Furnaces, Embreville, Tennessee, U.S.A.	R. A. Hadfield, J. E. Stead, Alexander Jack.
Jones, Edward Peter .	Ireton Lodge, Wolverhampton	Sir Benjamin Hingley, Alex. McBean, A. W. Hutton.
McNeill, William . .	Broad Street House, London, E.C.	W. C. Roberts-Austen, C.B., R. E. Commans, F. W. Harbord.
North, Harry . . .	Lemonwell, Eltham, Kent	Sir William T. Lewis, Arthur Keen, Sir James Kitson.
Onions, Zachariah Webb	Wainfelin, Pontypool, Mon.	R. Laybourn, Henry White, G. W. Wilkinson (Newport).
Pickering, Robert Young	Railway Waggon and Wheel Works, Wishaw, N.B.	Sir William Arrol, James Riley, A. T. Walker.
Radcliffe, Henry . .	Ashdene, Penarth, Glamorganshire	Edw. P. Martin, David Evans, Enoch James.
Richards, Frederic Windsor	3 Moorland Terrace, Leeds	David Evans, John D. Ellis, A. T. Walker.
Robinson, Charles Lawson	214 Chepstow Road, Newport, Mon.	Robert Hedley, A. B. Cowan, H. W. Hollis.
Rutherford, George .	Mercantile Pontoon Co., Limited, Cardiff	Edw. P. Martin, David Evans, A. T. Walker.
Ryland, Frederick Chesterfield	Exchange Buildings, Birmingham	Alex. E. Tucker, Joseph Cook, A. W. Hickman.
Sheppard, Oliven . .	The New Foundry, Bridgend	William Evans (Cyfarthfa), Benjamin Jones, John R. Wright.
Smith, Prof. Robert Henry, Assoc. M. Inst. C.E.	Ellerslie, Sutton, Surrey	Jeremiah Head, Thomas Turner, Walter G. McMillan.
Steel, Charles Ball . .	Park Side, Blaenavon, Mon.	P. Williams, D. J. Hirst, W. O. Dayson.
Stephens, Alfred . .	Dinas Silica Works, Kidwelly, Carmarthenshire	Ewd. P. Martin, William Williams, Thomas J. Williams.

NAME.	ADDRESS.	PROPOSERS.
Stevenson, John . .	Middlesbrough	John G. Swan, Walter Johnson, William Hanson.
Truran, William . .	Sirhowy Cottage, Tredegar	D. R. Jones, T. B. Hirst, David Jenkins.
Thomas, Hubert Spence .	The Cottage, Lydbrook, Gloucestershire	Josiah T. Smith, R. Beaumont Thomas, Edw. P. Martin.
Ward, Thomas William	Fitzalan Chambers, Sheffield	Arthur Horsfield, Joseph Cook, E. Windsor Richards.
While, Arthur James	Barrow-in-Furness	William F. Egerton, J. M. While, Thomas Danks.
Wight, Robert Murray	42 Exchange, Cardiff	W. Thackray, Jun., W. W. Hood, S. Gething Lewis.
Worton, Harry . . .	Park Terrace, Merthyr Tydvil, Glamorgan-shire	William Evans (Cyfarthfa), John Paton, Christmas Evans.
Wyman, Horace Winfield	Messrs. Wyman & Gordon, Worcester, Mass., U.S.A.	Henry M. Howe, Charles H. Morgan, Jerome Wheelock.

The PRESIDENT said the next business was to proceed with the reading and discussion of the papers, and he would call upon Mr. Wrightson to read his paper on the application of travelling belts to the shipment of coal.

ON THE APPLICATION OF TRAVELLING BELTS TO THE SHIPMENT OF COAL.

BY THOMAS WRIGHTSON, M. INST. C. E.

THE cruel breakage of coal in the ordinary gravitation system of coaling ships has led the author to consider in what way and to what extent the work of gravity could be controlled by mechanical means.

Of late years great strides have been made in the application of travelling belts to the movement of coal at the pit-mouth; but the difficulties arising from necessary changes in direction of the flow of coal from horizontal to vertical when passing into a ship, the fluctuations in the level of the water in which the ship to be loaded floats, the gradual sinking of the vessel as the coal fills the hold, the varying size of hatchways, and many other difficulties, have prevented the belt being applied to the shipping of coal.

It is not the author's object to do more on this occasion than generally to describe the way in which he proposes to overcome these difficulties; and as he hopes in a short time to have the first machine at work on the Tyne, he trusts that all those who take an interest in the solution of this important problem will take an opportunity of seeing for themselves how far this has been accomplished.

The best idea of the proposal will be obtained by an examination of the working model and drawing before you, both representing to scale the machine which is now erected at the staithes of the Cramlington Coal Co. in the Northumberland Dock on the Tyne, and was designed by the author in conjunction with Mr. Morison, manager of the Cramlington Co., and erected by Messrs. Head, Wrightson & Co., of Stockton-on-Tees.

The coals in this case are brought in at a high level, and are discharged into a hopper immediately above the end of a travelling belt.

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A door on the lower end of the hopper, of dimensions sufficient to pass the largest piece of coal, allows the tail end of the heap to run out on a slope upon the surface of the belt.

This belt, in moving forward towards the quay, draws the coal naturally and quietly down the slope through the door, filling the belt with a certain thickness of coal, which travels on to the edge of the quay.

At this point it is received by another belt which is mounted on a jib, the outer end of which can, by gearing, be lowered or raised to suit the level of the ship to be loaded.

The coal is carried along this second belt until it arrives at the end of the jib, the position of which is adjusted so as to plumb the hatchway.

At the end of the jib is suspended a vertical belt, which moves in a trunk. This belt has large trays upon every alternate plate. These, in turning round the top drum, form themselves into large hoppers, the back of the advance tray and the front of the following tray forming a hopper, with sides radiating to the centre of the top drum. Into this naturally-formed hopper the coal from the end of the jib belt is directed. As the trays clear the top drum they descend in the trunk, the coal being quietly lowered until it arrives at the level of the coal in the hold, where it discharges itself as the belt passes over the lower drum of the vertical belt.

The whole machine is self-contained upon a platform which can be moved forward and backward by the same power that drives the belts. In addition to this loading of the coal, the bulk of the trimming is effected by the machine, as the jib is arranged to slew right and left over a space equivalent to the length of the hatchway, and the vertical trunk being on a swivel joint at the end of the jib, can be deflected into a position which enables the coal to be delivered under the combings of the hatchway, thus saving a great portion of the cost of trimming, and the further breakage involved in that operation.

The belts are all driven by an engine, and the man in charge can control them, also the raising and lowering of the jib, and the racking in and out of the platform by handles and clutches placed in a convenient position.

As an alternative to the vertical belt, a large rectangular or

circular trunk or box can be suspended from the jib to receive the coal from the second belt. In this trunk a large valve is arranged at the bottom, which, on being opened, allows the coal gently to flow into the hold of the vessel at the same speed at which the top is being filled from the jib belt, thus keeping the trunk always full. This valve can be controlled by a cataract or other form of brake, and made so that after the trunk is emptied the valve rises to the top of the trunk ready to receive the next supply of coal.

DISCUSSION.

Mr. WRIGHTSON said that the special feature of the vertical belt was the way in which the coal was delivered, not into the side, as had been previously attempted, but into the top. As the belt turned over the upper drum, there was a natural motion of the trays, which, opening radially, formed themselves into a succession of natural hoppers, and into each hopper thus formed the coal was directed from the end of the jib belt; it was then carried down and quietly discharged as the trays turned round the lower drum. He did not propose to do more than just describe the machine as it had been erected on the staithes of the Cramlington Coal Company. They had at that colliery been so far satisfied with the work of the apparatus, that they were now making special arrangements for hoppers to supply the machine, which they had found possessed a capacity for delivering the coal much greater than the means they at present had for supply from the waggons to the belt. Perhaps Mr. Morison could give the meeting some information with regard to the way in which the machine was worked at the Cramlington Collieries.

Mr. J. MORISON said that a full-sized machine had been put up by the Cramlington Coal Company in the Northumberland Dock in the Tyne. The arrangement was so far temporary that they used an old spout to supply the machine, but the machine itself was of full size, and was the practical working machine which they had been using experimentally for some weeks. Its capacity was much greater than had been originally intended. It was designed to ship at the rate of 250 tons an hour; but it was found that so far as the mechanical arrangements of the belt were concerned, it was capable, at a very moderate speed, of taking coal away from the waggons at the rate of 400 tons an hour and upwards; in fact, he did not think that they had yet gauged its capacity in that respect. The staithes, or the gangways which brought the waggons forward, were merely temporary, and they could not supply the belts fast enough, so that they could not actually gauge the consecutive shipments; but calculating from the time taken to deal with one waggon when it was put upon

the belt, he had ascertained that at the speed they were instructed to drive the belt at, they could take away at the rate of 400 tons an hour. They were now so far satisfied with the plant that they had arranged to alter the gangway and put it in a permanent condition.

After Mr. Wrightson's explanation of the working of the machine, he need only say that, so far as concerned the manipulation of the machine towards the ship, which was done by running the whole thing back on rails as a locomotive, and dropping the trunk into the hatchway, they had not the slightest difficulty. The only trouble they had had was through the breaking of some of the transmitting chains—not the belt chains, but the link chains which transmitted the motion—which had given some little trouble owing to their being put in too weak. Otherwise it might be said that the working of the machine was mechanical perfection.

With regard to the condition of the coal after being shipped, it was impossible to give any definite statement until a cargo had been tested after being shipped by the old method and by the method described in the paper. Before committing themselves to any statement on that point, they proposed to test a cargo in the way he had mentioned. It appeared to him, however, speaking generally, that the machine was a considerable improvement over the old system. He thought he had put the capacity of the machine very much below the mark, and he saw no difficulty in shipping much larger quantities than he had mentioned. So satisfied were they, that they were determined to carry the thing on. He thought that the problem had been to a great extent solved of putting the coal into the hold of a ship with much less breakage than had hitherto obtained.

Mr. T. FORSTER BROWN said he was much struck with the model of the machine when he first saw it in London. How far in its present form it would suit the South Wales coal was, he thought, open to question. The South Wales coal was not cubical in structure like the North Country and other coals, but large and angular in form, and the hopper or bucket ladder as proposed would have to be modified in form, and the boxes made much larger, if they were to be adopted with success in

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South Wales. He should be glad to hear what Mr. Morison had to say on the question of trimming, which Mr. Wrightson had made a considerable point of, because that was a very important feature in regard to the saving in breakage as well as labour. So far as his judgment went, he thought that the design was a most promising one, but before deciding whether it would work in practice, they must wait and see the results of the further experiments mentioned by Mr. Wrightson as in hand at the Cramlington staithes under Mr. Morison.

Mr. A. TANNETT WALKER, Member of Council, said he had only seen the model for about five minutes at the *Conversazione* of the Institution of Civil Engineers in London, and he did not consider himself sufficiently acquainted with it from a mechanical point of view to give any opinion as to its future utility. The great difficulty he saw in it was this: a contrivance of that kind was all very well for grain and for anything which was all of the same size. For slack or anything of equal form and size, such a contrivance would act admirably; but great, ugly lumps, such as they had in South Wales could not, he thought, be very easily dealt with. They would not be led—they would not do exactly as they were told; they first jogged this way and then jogged that way, and would be apt to put out of gear the driving belts and the gearing. The scheme appeared to be a good mechanical one, and looked very simple. He did not want to be a prophet and say that it would not answer—it was always dangerous to say that a thing would not answer—but he thought it would be very difficult to apply it to South Wales coal. He could quite understand its being used on the Tyne. The coal there was not so friable and was not of the same shape as that in South Wales. When the members had had the opportunity of visiting the Bute Docks and seeing the coal there and the mode in which it was dealt with by the Lewis and Hunter scheme, he thought they would see that although Mr. Wrightson's scheme was an admirable one, it was not really adapted to Welsh coal.

Mr. FORSTER BROWN said he thought that those who were connected with South Wales would not admit that South Wales coal was more friable than the North Country coal.

MR. JEREMIAH HEAD said that Mr. Wrightson had been kind enough to show him his model some time since in London, and he must say that he had been struck with its ingenuity and the thought and care that had been bestowed upon the machine it represented. It was, as would be seen by all, an extension of the system which had been long and successfully applied to the loading and unloading of corn, to the loading of coal, which was a somewhat more difficult thing to accomplish. Although Mr. Wrightson's invention might, so far, not be applicable to all kinds and sizes of coal, it must be admitted that it was an exceedingly promising one, and if it proved successful with one class of coal, it would probably soon be adapted to all classes. If coal was to be loaded by machines at all, it would not be in isolated cases. Success would be followed by their general use, entire ports or docks being fitted up with them.

When it came to that, he questioned the desirability of having a separate engine for each machine, as shown in the model. He thought it was a most appropriate case for the application of electricity. No one knew better than Mr. Wrightson that steam power applied more or less intermittently, as that would be, and where the average load factor must be a very low one, would not be an economical application; whereas if there were several machines, and they were all driven electrically from a central generating station, the power could be generated under the most favourable and economical conditions. And not only so, but it would be observed that this machine comprised a good many movements, some of which were driven by clutches from a long shaft. Mr. Morison had also referred to the transmission of power by chains and sprocket wheels. All those things would be done away with if electricity were applied, because there might be a separate motor to every movement. He was not making these remarks in the way of any unfriendly criticism of Mr. Wrightson's very excellent machine; but simply in the hope that in any further development of it he would consider the desirability of applying electricity throughout.

It also occurred to him that the transmission of the coal by belts would afford an excellent opportunity for final sorting, so as to improve the value of the coal. They might have a platform for boys or men to stand on and pick out any pieces that

might have shale in them. It did not appear to him that the 250 tons an hour which had been mentioned was a very large quantity. But Mr. Morison had said that 400 tons per hour could be shipped by the machine, and that without any lifting or lowering or tipping of trucks or anything of that sort. That was no small thing to have been accomplished.

He did not know whether all members sufficiently appreciated the importance from a national point of view of avoiding disintegration in the handling of coal. When they remembered that the value of coal in the form of coal-dust was certainly not more than half the value of round coal, they must see the extreme importance of saving in that respect. Round coal was of high market value—8s. 6d. to 9s. per ton f.o.b., being the present price in the North of England, while small coal was not worth more than 3s. 6d. to 4s. It was easy to see that every ton of coal retained as round coal, instead of being turned into small, was a positive national benefit; and he thought that Mr. Wrightson was to be congratulated on the efforts he was making to save loss in that respect.

Mr. T. HURRY RICHES had listened with great attention to the remarks which had been made in reference to the belt method of shipping coal, and he could not help thinking that what Mr. Walker had said was highly applicable to that particular method. They had in South Wales large lumps of coal, some of them 2 or 3 feet long, and he was afraid that in cases of that kind it would be very difficult to deal with it by Mr. Wrightson's machine. Again, the shape of the coal was very different from that in the North of England. Many members were no doubt aware that the cleavage of the North Country coal was more or less cubical, while the Welsh coal was very irregular; therefore the tendency to jam in anything like a confined passage in the way suggested was very great, and he feared that some trouble would arise in consequence. Mr. Head had remarked that the tipping of 250 tons an hour was very good work. People in South Wales would hardly agree with him, because they sometimes got nearly three times that amount tipped from one tip.

When the future requirements of the district were considered, whatever appliance might be adopted, the more rapid shipment

of coal should be brought prominently into view. To arrange for a shipment of 250 tons an hour would certainly not meet with any consideration in South Wales. They wanted to go faster, not slower, than at present; and they also wanted to prevent breakage. Any system that would prevent breakage would, of course, be most desirable, particularly in regard to South Wales coal; but that was not the only thing to be considered; they also wanted to increase the quantity. A large amount of coal had to be shipped through and through, and therefore Mr. Wrightson's system would be quite out of the question. What was wanted was to ship 700 or 800 tons an hour. He submitted that for the consideration of Mr. Wrightson, and he hoped that when he was developing his scheme in the future he would bear in mind that rapid despatch was essential.

Mr. JEREMIAH HEAD said he had not intended to convey the idea that 400 tons per hour was an absolutely satisfactory performance, but simply that it was a very creditable one under the circumstances explained by Mr. Morison.

Mr. PRICE WILLIAMS was glad to be afforded the opportunity of supplementing some remarks that had fallen from Mr. Head. In Mr. Wrightson's interesting paper in regard to the subject of the waste by coal breakage, Mr. Morison had laid great stress on the large quantities of coal delivered by Mr. Wrightson's coal-shipping appliances; he did not think, however, that either in the paper or in the discussion upon it sufficient attention had been directed to the enormous waste occasioned by the breakage of coal.

He might mention that in the discussion upon a paper on a kindred subject recently read at the Institution of Civil Engineers, he had alluded to the fact that he had given a good deal of attention to the subject of the breakage of coal whilst it was being unloaded from the railway trucks into the coal-bins of the Great Northern Railway, and that it had fallen to his lot, when a resident engineer on that railway, to make a series of careful experiments for the purpose of determining what the actual amount of loss due to this breakage was. The coal had previously been allowed to drop about 10 feet from the waggon

to the bottom of the coal-bins. By means, however, of a very simple and ingenious coal-drop invented by Mr. Samuel Plimsoll—whose name is well known in connection with overloaded ships and the Plimsoll Mark which all British ships now bear—the coal is not allowed to fall at all, but by means of inclines slides down into the coal-bins. The results of the experiments he (Mr. Price Williams) carried out at King's Cross, with the sanction of the then General Manager, Mr Seymour Clarke, showed that there was a saving of a little over 1s. per ton entirely due to the saving in breakage. The South Yorkshire coal he had to deal with was more friable than South Wales coal; the destructive effects, however, resulting from allowing coal to fall at all were much greater than was generally imagined. The Great Northern Company was so satisfied with the saving from breakage obtained by means of Mr. Plimsoll's coal-drop, that they entered into an agreement with him to construct the now well-known coal-drop at York Road, King's Cross, and subsequently a lease was granted him by the Company to work these coal-drops for a period of about thirty-five years, one-half the estimated saving of 1s. per ton being allowed Mr. Plimsoll, and the Company crediting themselves with the other half.

The lease of these coal-drops only expired a few months ago, and by a curious combination of circumstances it fell to his (Mr. Price Williams's) lot to have to assess with the Company's engineer the value to Mr. Plimsoll of the plant and appliances that had to be handed over to the Railway Company. These coal-drops continue to be worked by the Great Northern Company, and the system of working is now generally adopted on the Midland and other principal railways. He was quite satisfied that in the beautiful working model exhibited by Mr. Wrightson they had all the essential requirements of a most important and effective method of shipping large quantities of coal with rapidity and a minimum amount of breakage.

Mr. Morison had spoken of 400 tons an hour being shipped, as compared with the 250 tons Mr. Wrightson had mentioned as the present amount, but of course they could not anticipate that perfection would be attained at once; it was evident, however, that, with some slight modifications, much larger quantities of

coal could be shipped in a given time by Mr. Wrightson's method.

Notwithstanding the remarks of Mr. Riches as to some difficulties in the working to which he had drawn attention, he could not help thinking, when attention was being drawn to them, of the reply he lately heard Sir Benjamin Baker (the designer and constructor of the Forth Bridge) make when taken to task by a distinguished counsel on the ground of the engineering difficulties involved, and who merely remarked with a smile, "I do not think much of difficulties, but in overcoming them." He felt satisfied that the development of this admirable coal-shipping machine would, in a short time, result in 600 tons of coal per hour being shipped.

With regard to the amount of breakage of coal, he was quite sure that coal-owners had not an adequate idea of the large pecuniary loss attending it, even in the case of Welsh coal. That the loss attending this breakage of coal would be largely reduced by Mr. Wrightson's method there could be no doubt, and he hoped it would meet with the success it deserved.

The PRESIDENT thought Mr. Price Williams was not quite correct in saying that people in South Wales did not appreciate the loss arising from a large quantity of small coal. In that district as well as in others a great deal had been done to avoid that loss. Improvements had been made in loading cranes; and in some cases, where coal had been shipped to South America, the sellers of coal had been bound to undertake that the coal should be loaded by the Lewis and Hunter cranes, in preference to the ordinary shoots, in order to avoid breakage. He looked forward with great hope to the adoption of some such system as Mr. Wrightson had shadowed forth, which would eventually lead railway companies to do away with the twopenny-halfpenny trucks which they now ran; so that instead of having 7 or 8 or 10-ton coal trucks, they would soon run 50-ton trucks and have their rates reduced in proportion.

One of the great difficulties of the dock-owners in running large trucks would be in handling them round present curves, which, with the present arrangements at the docks, would be a serious matter; but he was dreaming of a time when all

the coal in those large trucks would be placed into large bunkers, and from those bunkers coal would be led by some system or other into the holds of the vessels with little or no breakage. He also wished to direct the attention of the members to another very important question which he thought had been allowed to remain pretty much as it had been for the last fifty years. In unloading vessels carrying iron ore or coal, they were now practically dealing with them in the same manner, with tubs and shovels, as they did forty or fifty years ago. It did not much matter then with sailing vessels what the demurrage was; but in these days every hour in the case of a large steamer was of very great importance. If they could reverse Mr. Wrightson's machine, and make it available for unloading iron ore, he certainly would deserve the best thanks of the iron and steel makers.

Mr. WRIGHTSON, in reply, said he had omitted to mention one feature in his description of the machine. In order to spread the delivery of the coal, he arranged differential speeds on the belts. In the case of the Cramlington coal-shipper, he gave a speed of 40 feet per minute to the first or shore belt, 60 feet to the second or jib belt, and 80 feet to the third or vertical belt; and the result was that if any accumulation of coal took place in one part of the shore belt, when it arrived at the next belt, which was moving at a speed half as great again, the coal was spread forward, so that there was no crowding. Several speakers had alluded to the quantity of coal mentioned by him—250 tons an hour. Although he designed the machine for that delivery, the only reason was that this was all they required at the Cramlington staithes. The principle could, however, be easily extended in its application, and the quantity increased, either by increasing the velocity of the belts or their width. As a matter of fact, by a slight increase in the speed of the motor a rate of 400 tons per hour had been easily attained, and he had no hesitation in saying that he could take 800 or 1000 tons, if he were asked to do so. It was only a question of size and velocity of belts.

The power, as Mr. Walker well knew, could be easily adjusted. They would have to make the machine and the tackle a little stronger, but this was a matter of no difficulty. He thought

that many a good appliance was spoilt from people being afraid to make it too strong and too big. They had to make this machine strong enough for what was required. He had frequently stood on the ship's deck while the loading had been going on with his machine, and watched the flow of the coal as it was carried forward on the belts and quietly and naturally deposited at the bottom of the hold. He thought that any one who saw that—and he hoped that many would see it—would say that there ought to be no difficulty in increasing the quantity to any reasonable extent. Mr. Riches had spoken of the quantity of coal shipped in the Cardiff Docks being much greater. He (Mr. Wrightson) thought he had seen some returns which did not go beyond 500 tons an hour, shipped by three machines. If 500 tons required three machines, he thought that his own machine was much more powerful.

The PRESIDENT said he believed that 11,000 tons had been loaded in a vessel in forty-eight hours.

Mr. WRIGHTSON asked how many machines were used?

The PRESIDENT said he believed there were two machines.

Mr. WRIGHTSON said that Mr. Brown and Mr. Walker had referred to the size of the coal in South Wales and its friability. Of course, the size of the coal was greater than that of the Northumberland coal. Before constructing the machine, he asked Mr. Morison what was the maximum size of the coal required to be dealt with; that maximum size was given, and he (Mr. Wrightson) made the machine to suit it. If any one asked him to design a machine for Welsh coal, he should ask the same question, "What is the maximum size of the coal you want to pass down the trunk?" and he would make the trunk the size required. It might have to be a foot larger each way than in the case of the Northumberland coal. The only question was, What was the size of the coal to be dealt with? and the trunk could be made to suit the requirements. That he thought was a sufficient answer to the question about the difficulty in the application of the machine to South Wales coal. Mr. Head

had referred to the question of the motive power. In the case in point, the steam-engine had been used because they had one available for this experiment, but they had all along considered that where there were more machines than one, it might be desirable to work them by electrical power, or, if more convenient, by hydraulic power. In the case of the Cramlington machine, the trays were three feet wide, two feet deep, and two feet between the trays. That was found to be an ample size for all the coal. They had a gauge which would stop any piece of extraordinary size which might be beyond the dimensions of the machine.

Mr. Price Williams had made some interesting remarks on the subject of loss by breakage. He quite agreed that coal-owners did not know what a loss it was to them to have broken coal. He believed that the way in which a buyer of coal judged of it was largely by its appearance. He admitted that it was a most difficult thing to judge of the percentage of small coal, and it could only be shown by very elaborate experiments. The method suggested by Mr. Morison of taking two cargoes, one shipped by the ordinary appliances, and the other by his (Mr. Wrightson's) machine, and then unloading and riddling the coal, was the only way of really ascertaining where the advantage lay. But upon the face of it, any one who saw the quiet way in which the coal was deposited at the bottom by his machine, would, he thought, admit, without more elaborate investigation, that the saving in breakage must be very considerable indeed.

He did not know that he had anything further to say except to allude to the President's remarks as to the size of the trucks used. The President had distinguished himself by the way in which he had tackled the subject of enlarging railway trucks in the presidential address which he had delivered at the London meeting. He had, in fact, identified his name with that subject, and it was to be hoped that he would continue to do so. They had to look very largely for their future success in trade to a decreased cost of carriage in this country; and in regard to the application of big trucks, he thought that the larger the truck used in shipping coal the better. It would not affect the question of discharging, because it was just as easy to discharge a large truck as a small one, if it was properly arranged. No doubt

a machine of that kind at once suggested the idea that by reversing the operation a system of unloading could be arranged. The difficulty was, that unless they shovelled the coal into the trays of the vertical belt and reversed the operation, in that way it would not be applicable. But there were other ways of doing it, and he hoped on a future occasion to describe a patent that he had taken out for that very purpose. It was, however, no use going into this, when the object was to discuss the particular question brought forward in the paper.

The PRESIDENT said it was his duty and pleasure to propose a hearty vote of thanks to Mr. Wrightson for his interesting and able paper.

The vote of thanks having been carried by acclamation,

The PRESIDENT announced that all the candidates had been elected in accordance with the Rules, and he begged to thank the scrutineers, Mr. Ashbury and Mr. Head, for their services. He had also to announce that the vacancies on the Council, caused by the lamented death of Mr. Thielen, Vice-President, and by the election of himself (the President), had been filled by the Council by the appointment of Sir William Lewis, Bart., and Professor W. C. Roberts-Austen, C.B., as Vice-Presidents, and of Sir E. H. Carbutt, Bart., and Mr. Greiner as Members of Council. In making the last appointment, they had taken into careful consideration the fact that the Institution was a cosmopolitan one, and they had unanimously elected Mr. Greiner to fill the place of the late lamented Mr. Thielen.

The following paper was then read:—

THE MANUFACTURE OF TIN-PLATES.

BY GEORGE B. HAMMOND, PENARTH.

IN accepting the invitation of your Council to prepare a paper on the manufacture of tin-plates, I am keenly alive to the difficulty of doing justice to a subject which has been so ably dealt with in the interesting papers read before the Institute by Mr. Ernest Trubshaw and by the late Mr. P. W. Flower. I venture, however, to undertake the task, as considerable progress has been made in the science and practical mode of manufacture during recent years, and, however unworthy my paper may be in itself, the subject has an important bearing on the steel trade of the country, and claims more than ordinary interest for this district in which you are now meeting, as the neighbouring town of Pontypool was the birthplace of the British tin-plate trade, about the year 1665, when, under the auspices of the Hanbury family, Mr. Andrew Yarranton made an attempt to establish the manufacture there, on knowledge obtained by him in Saxony, where the trade was at that time in a flourishing condition. Mr. Yarranton's undertaking produced but little results at the time. Other active minds were, however, apparently engaged in the same direction, for it is recorded that one William Chamberlaine took out a patent in the year 1673 for "a newe arte, mistery, or invencon of great use, &c., for plateing and tynning of iron, copper, steele, and brasse, as also for compressing and plateing of all other metallis;" which invention related to the use of certain "engines or instruments and wayes and meanes" of tinning and plating iron, &c.; and eighteen years later, in 1691, John Hemingway was granted a patent, owing to influence at the court of William and Mary, for the sole use for fourteen years of an invention for "makeing of iron plates tynned over, commonly called tynned plates."

This latter patent, though never actively used, was the cause of the industry being abandoned for a time at Pontypool, until, in the year 1720, Major John Hanbury re-started the Pontypool

works; but his venture was attended with little success for some years. The method of producing was slow and laborious, the operation being that of flattening out hot slabs of iron under a quick-action helve or tilt-hammer, the pieces, as reduced in thickness, being doubled over and piled with other pieces reduced in the same way, the surfaces being sprinkled with powdered coal or charcoal to prevent welding, the hammering being continued until the required size and thickness were obtained. The plates were afterwards steeped in a weak solution of sour rye-water or vinegar for several days to remove the oxide and other injurious substances formed on the surface of the plates during the operation of forging, and, when cleaned, were immersed in a bath of molten tin.

In the year 1728 Major Hanbury and John Payne brought out an invention for rolling sheet-iron, and it was found that plates produced by this new method possessed a finer surface, were more uniform in thickness, softer and more pliable in working, and were much esteemed by the consumers of the time.

The trade then spread to some of the neighbouring works of Monmouthshire and Glamorganshire, and in some few instances to the other ironmaking districts. The development was gradual, but the production was soon sufficient for the requirements of this country, and the imports from the Continental works ceased. It was not, however, till the present century that the trade made any rapid strides, when, by the advances of science and civilisation, the uses to which tin-plates may be applied in the canning of fish, fruit, other food-stuffs, and oil became known.

The trade, however, gave constantly increasing employment to the labouring classes of South Wales and Monmouthshire, a district which has retained its position as the principal seat of the manufacture for more than 150 years, extending to recent times. Whole families have engaged in the industry in the same localities from generation to generation, until their present representatives, with some reason, look upon the trade as their birth-right, and regard with jealous eyes the now rapid growth of the manufacture in other countries, preferring, in times of depression, to follow the trade into distant lands rather than engage in other occupations at home. It is a noteworthy fact, also, that wherever

tin-plate works have been established within recent years, Welsh workers have been required to instruct the native labour and to assist in the development of the art. At the present time employment is found in this country for many thousands of workpeople in the industry itself, and many thousands more in those trades which are dependent on providing the materials from which tin-plates are produced; one instance of which is the fact that more than half-a-million tons of British steel bars are annually produced for the purpose, some of our largest steel-works being partially, and in some instances wholly, employed in manufacturing this material. The expansion of the trade in this country over the last thirty years has been very marked, and the extent of it may be gathered from the following statistics, taken from the Board of Trade returns, representing the shipments to all countries of the world, and taken at intervals over the period named, but they do not include the plates produced for home consumption, nor—as regards the periods to 1895—the blackplate shipped for coating abroad:—

Year.	Weight.	Value.	Average Price.
	Tons.	£	£
1867	78,906	2,060,410	26·11
1872	118,083	3,806,973	32·24
1877	153,226	3,033,126	19·80
1882	265,039	4,642,125	17·51
1887	353,506	4,792,854	13·56
1891	448,379	7,166,655	15·98
1892	395,449	5,330,216	13·48
1893	379,172	4,991,300	13·16
1894	353,928	4,338,786	12·26
1895	366,120	4,239,193	11·58
	Blackplate }	338,346	...
	34,368 }		
1896	266,963 }	3,036,015	11·37
	Blackplate }	477,999	...
	48,405 }		

It is interesting to note in the above figures the gradually declining values of the material, and it is doubtless this which has in the past given the stimulus to the trade, and has largely added to the uses for which the material has been adapted. The largest exports were in 1891, and until that year the industry had been almost entirely confined to this country, and the American market was supplied solely from Wales; but with the introduc-

tion of the McKinley Tariff, which increased the import duty to 2·20 cents per pound (equivalent to 10s. per cwt.), works were established in the United States, and these have since been operated with considerable success. The growth of the industry there has been very rapid, the estimated output for the years ending June 30th, 1892-1896, being as follows:—

	Tons.
1892	5,803
1893	44,196
1894	62,053
1895	86,160
1896	137,053

In a report lately prepared for the British Foreign Office, it is stated that there are now 180 mills in existence in the United States, 170 of which are working, eleven new ones are in process of construction, with a total potential capacity of 6,250,000 boxes, about equal to the total American consumption in 1896, and the present production is stated to be variously estimated at from 4,000,000 to 5,000,000 boxes a year.

The imports of British tin and terne plates into the United States have rapidly declined in these years, thus:—

	Tons.
1891	325,143
1893	280,546
1894	226,880
1895	223,077
1896	113,049

France, Germany, Italy, Spain, and Austria are also producing, and the Welsh makers are anxiously seeking fresh markets abroad. In the meanwhile great depression exists. Of the 490 mills in Great Britain at the present time, only 302 were in operation at the end of April.

During the last fifteen years a great revolution has taken place in the trade by the general adoption of mild steel as a substitute for iron bars, which were formerly produced in the charcoal and puddling forges attached to the tin-plate works of the district, with the result that these forges have been entirely abandoned and the tin-plate trade proper may now be considered to commence with the rolling of the steel bar into blackplate, although some of the larger works have erected open-hearth steel plants.

It is my intention, however, to deal with the manufacture commencing with the steel bars.

For this purpose mills are employed consisting of two pairs of rolls, the first pair for breaking or roughing down the steel bar into plate form, and the second for finishing the plates.

Two heating furnaces and two pairs of shears, to one of which is attached a doubling table and squeezer for doubling and flattening the sheets after elongation between the rolls. The rolls are made of a mixture of strong, tough, cold blast iron, cast in chills. Before being put to work the necks and bodies are turned in a lathe. After being put in position in the mills the bodies are again dressed and fitted to each other, to work even together when expanded at their work.

I may here mention that the general practice in the United States varies by employing one pair of rolls only in a mill, the operation of roughing down and finishing being performed in the same pair; or in some cases three pairs of rolls are employed for two mills, one pair doing the roughing down for the two finishing.

The furnaces are of the reverberatory type, and the bars and sheets charged on the bed of the furnace are acted on by the flame from the grate placed at the back. Defects or wasters are sometimes produced by particles of small coal and ash being carried forward from the grate or picked up from the bed of the furnace, and subsequently rolled into the surface of the sheets. In some modern works, gas-producers are employed for supplying the furnaces with fuel, and beneficial results are obtained as regards quality of plates produced and the decrease of wasters.

The workmen employed in the mills are formed of sets, consisting of a roller, doubler, furnaceman, and catcher—the roller being the head and having charge of the mill. Three sets are employed for eight hours each in a day of twenty-four hours for five days in the week, and one set on the Saturday; the mills running continuously from Monday morning till midday on Saturday. A shearer and three openers generally cut and open the work from each mill.

The operation is as follows:—The rough bars from the steel-works, of suitable gauge, varying from $\frac{1}{4}$ to $\frac{3}{4}$ inch thick and 7 to 10 inches in width, are cut into short lengths corresponding

with the width of the plates to be produced, and are placed in the first or thick-iron furnace, and when heated to redness are delivered to the roller, who passes each piece several times between the roughing rolls; the catcher, stationed behind the rolls, catches the pieces as they pass through, and returns them over the top roll. When sufficiently extended, the pieces are replaced in the same furnace, and heat equivalent to that lost in the operation of rolling is restored. When they are again extended by rolling, the doubler doubles the two ends of each piece together, flattening the piece under the squeezer, by which it should be observed the substance for resistance in the next operation of rolling is not diminished. In this stage the pieces are known as "doubles." The doubles are now charged into the second or finishing furnace, leaving the thick-iron furnace free to heat another charge of rough bars while the operation of finishing the former is continued. When the "doubles" are heated the pieces are again extended, the second doubling is performed, and the uneven ends are cut off at the shears; "fours" being thus produced. The packs are again subjected to the action of the finishing furnace and prepared for final rolling, or the process is continued after further rolling and doubling to "eights," as may be necessary for the gauge required. It is customary in every instance after two or more thicknesses of doubled plates have been rolled together to separate them before reheating, care being taken to replace the pieces in position in the pack; this avoids welding of the surfaces and facilitates the final separation or opening of the finished sheets. It is known that each piece of rough bar of given weight, if carefully manipulated, will produce so many sheets of the desired size and gauge, and considerable skill is required to obtain sufficient length and at the same time to avoid exceeding it, or the steel would cut to waste. When the roller is satisfied that he has obtained the above requirements, the pieces are placed on trolleys for conveyance to the finishing shears, and when cool are cut by the shearer into the sizes of the order in hand.

The next process is that of opening or separating the plates pressed together by the final rolling; for this girls are employed, who do the work by hand, separating sheet from sheet with much dexterity. In this state the plates are known as rough blackplate.

A machine, for which a big future seems possible, has lately been invented by Messrs. Williams and White, for opening or separating blackplate or sheets, and the following description may be found of interest:—

The machine consists essentially of two pairs of rolls, all driven at the same circumferential speed, and placed with their axes all parallel to each other. Between the first and second pair of rolls is placed a “waved guide,” consisting of hard, smooth, chilled iron plates. These plates are firmly held at a proper distance from each other, and the “guide” formed by the two plates is firmly held in position between the two pairs of rolls, as shown in Plate I.

The action of the machine is as follows:—The packs of unopened blackplate to be opened by the machine are passed through the first pair of rolls. From these they pass through the sinuous passage of the guide-plates. After leaving the last bend or curve in the guide, the second pair of rolls seizes the plates and draws the packs through, completing the operation. After leaving the second pair of rolls the packs fall on a trolley, where they accumulate until wheeled away for the next process.

It may be explained that the individual sheets comprising the pack are held together by very thin films of oxide of iron, which forms on the surface during the working of the sheets while hot.

As the packs are forced around the curves of the waved passage, the sheets of metal and the films of iron oxide are bent to and fro. This bending to and fro is harmless as far as the metal is concerned, but it is destructive to the films of oxide, hence the cementing medium is destroyed and the sheets are separated. The separation is further assisted by the varying velocities of the individual sheets in passing around the curves of the guides. For example, the sheet next the convex face of the guide travels slower than the sheet next the concave face. This sliding is seen by simply rolling a book with pliable covers, when the leaves step back from each other at the edges and the faces all slide on each other.

This sliding and bending is the principle upon which the machine is constructed, and the principle is the same as that of the method adopted by the girls of bending the corners of the packs when opening by hand.

One machine is capable of opening the work from four or five mills.

The average capacity of an efficient modern tin-plate mill is forty to fifty boxes (of 1 cwt. each) in eight hours; but until recently, under their Union rules, the work-people have been restricted to an output of thirty-six boxes; this cannot, however, be upheld, as the only hope for this country to retain a hold on the trade is to obtain big makes and to produce cheaply. The wages paid in the mills known as the "1874 List" are as follows:—

Roller, 3s. 5d. per dozen boxes = average of 10s. to 13s. per turn.
 Doubler, 2s. 9d. per dozen boxes = average of 8s. to 10s. per turn.
 Furnacemen, 2s. 7d. per dozen boxes = average of 7s. 6d. to 9s. 9d. per turn.
 Catcher, 1s. 3d. per dozen boxes = average of 3s. 9d. to 4s. 9d. per turn.
 Shearing, 1s. 1d. per dozen boxes = average of 10s. to 12s. per turn.
 Openers, 6s. 3d. per 100 boxes = average of 2s. 3d. to 2s. 9d. per turn.

Black Pickling.—This operation is necessary to clean the oxide of iron formed by the action of the air on the heated surface of the plates in the mills, and is now universally done by means of machines provided with cradles, in which the plates are packed on their edges in bulk, for immersion first in diluted sulphuric or hydrochloric acid to remove the scaly oxide, and afterwards in water to wash off all traces of acid; a quick, vertical, horizontal, or rocking motion being conveyed to the cradles to permit the liquid to circulate through and pass between the plates under treatment. The machines most in use are those made by Mr. David Grey of Maesteg, by the Millbrook Co. of Swansea, and by Messrs. Taylor & Struve of Briton Ferry, the essential difference in them being the modes by which the cradles are conveyed to and from the acid and water tanks, and by which the motion is applied to the cradles in the liquids.

Great economies have been effected in labour and in the quantities of acid required by these mechanical appliances over the old-fashioned hand-pickling in leaden vats, the tedious process that was employed twenty years ago.

Black or First Annealing.—The plates after leaving the pickling machines are packed in piles on iron stands, and are covered over with inverted iron or steel boxes, called pots, sand being used around the mouth to exclude the air. The

boxes with enclosed plates are then subjected to a mild flame in a large reverberatory furnace for eight to ten hours, and are then allowed to cool gradually, the object being to soften the plates, that they may be more easily polished in the preparation for tinning.

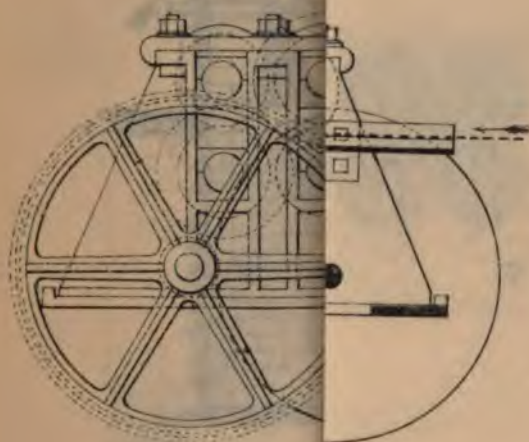
Cold Rolling.—This process consists of passing the plates one by one when cold three or four times between highly polished chilled rolls working under great pressure, and is necessary to remove any buckle or unevenness from the plate and to produce a flat, bright, polished surface for receiving the coating of tin. The plates are hardened by this process, and it is necessary to give them a second or white annealing, the plates being treated in the closed pots as before, but subjected to a milder heat. On cooling they are again soft, with a bright appearance, and are in this state called finished black plate. A second or white pickling is necessary to remove any oxide formed in the annealing processes. This process is performed in the same way as the first pickling, but the acid solution is weaker, and after the plates are removed from the swilling tanks they are kept in water until taken to the tin-pot.

Tinning.—In former times this process was performed by soaking the plates in the molten metal, and afterwards arranging them on edge in a rack fixed in the grease-pot to allow the surplus tin to drain off them, the thickness of the coating being determined, to some extent, by the length of time the plates remained in the hot grease. The process was very wasteful, and it was impossible by its means to obtain a uniform coating over the surface of the plates. About the year 1860 Mr. Edmund Morewood of Llanelly and Mr. John Saunders of Cookley invented machines with rolls placed in the grease-pot, to better regulate the quantity of metal, whereby an immense saving was obtained, and a superior and more evenly coated plate was produced. This method, with modifications in detail, continues to the present day.

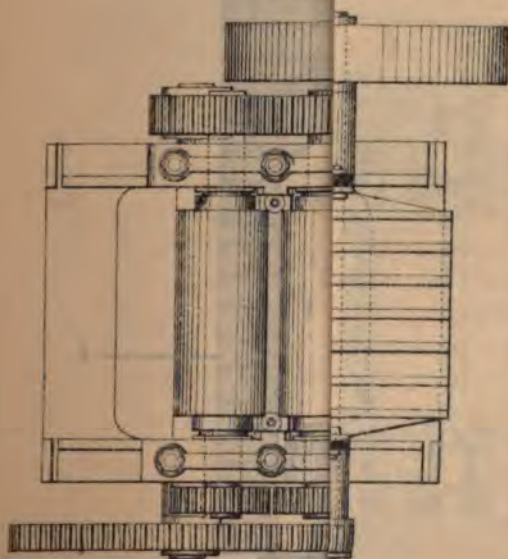
In the process as introduced by Mr. Morewood, the wet plates from the swilling-troughs of the white pickling machine were immersed, sheet by sheet, by the tinman, twenty-five to thirty at a time, in a bath of melted palm-oil to absorb the moisture on the surface of the plates, and then removed and dipped into a

THOMAS WILLIAMS

SIDE ELEVATION.



SECTION,
PLAN GUIDE REMOVED.



THOMAS AND W



PLATE II

OF MACHINE

FOR THE PURPOSE OF

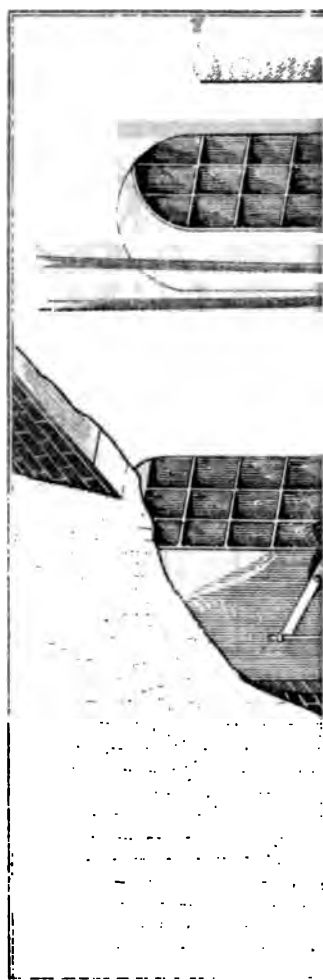
CONVERTING

STEAM INTO



END OF PLATE

1



1



ROLLING MACHINE

ary Stack

Plates raised from Bosh

Cooling Rack

Wheel for lifting Rolls out of Grease

Hopper

series of pots containing molten tin at various temperatures; and after being brushed, one at a time, on both surfaces by the washman with a hempen brush, they were conveyed by him to the grease-pot in which the rolls revolved. The plates, on issuing from the rolls in a vertical direction, were raised by a boy and placed in a rack, from which girls removed them to dip in bran, for the purpose of removing grease adhering to the surface. They were afterwards polished by slightly rubbing with a duster of sheepskin or other soft material, by which the coating operation was completed.

The capacity of modern machines employed in the above method varies from thirty to forty boxes in proportion to the number of rolls working in the grease-pot and the class of work in hand. The wages paid under the 1874 list are:—

Tinman, 3d. per box	= 7s. 6d. to 10s. per day.
Washman, 3d. per box	= 7s. 6d. to 10s. per day.
Grease-boy, 1d. per box	= 2s. 6d. to 3s. 4d. per day.
Dippers, girls (usually two), 7s. per 100 boxes	= 2s. to 2s. 9d. each per day.
Dusting, 6s. per 100 boxes	= 1s. 9d. to 2s. 4d. per day.

For years past attempts have been made to economise on this method, and to employ chloride of zinc as a tinning flux in substitution for palm-oil in the first pot, but the results for some time were not satisfactory, and large parcels of plates coated by the experimental processes arrived at their destination in a rusty condition, owing, doubtless, to the presence of free acid in the flux, and the porous nature of the iron coated; the workmen also strongly opposed the innovation, and found means to prejudice buyers and consumers against accepting delivery of any plates prepared by such methods, as injurious to the food products which would be packed in them; and it was not until steel came into general use, assisted, doubtless, by the more careful preparation of the flux, that any degree of success was attained in this direction.

It is now in general use, and by its means the operation of coating is much more rapidly effected and a brighter finished plate is produced; it has also been proved beyond the possibility of doubt that the material so used is innocuous to the fish, fruit, and other goods for the packing of which the plates are employed.

From this change may be dated the successful introduction

of mechanical tinning pots, by which further savings are effected in material and the services of the washman are dispensed with. These mechanical tinning pots, now known in the trade as "patents," are of various makes, the variations consisting principally in detail, each maker claiming some advantage for his machine over that of others. They may, however, be divided into two classes, in one of which the plates travel vertically, and in the other in a half-circular direction from the flux, through the tin, and into the rolls revolving in the grease-box end. Of the latter type, those of Messrs. Thomas of Melin-griffith, Daniel Edwards of Morriston, and Thomas & White of Llangennech, and of the former, those of Messrs. Taylor, Struve & Co. of Briton Ferry, and Player of Clydach are well-known machines.

Plate IV. represents a machine of the vertical type at work. This machine, patented in 1882 by Messrs. Taylor & Leyshon, and made by Messrs. Taylor, Struve & Co. of Briton Ferry, was the first single pot, for coating and finishing without the aid of the washman, to meet with practical success, and is still in use at many of the most important works to the present time, with very slight alteration in detail. The principle employed being that of drawing or pulling the plates by means of a nipping appliance working beneath the surface of the metal, through the flux into the tin in a vertical direction, so as to allow the plate to clear itself of any scruff adhering to it. The plates enter and leave the pot perfectly flat, and a coating of any quality may be produced, this being regulated by the speed of the rolls in the grease-box and by the quantity of tin in the troughs under the finishing rolls, which also tends to wash off any scruff taken up in the tin pot. The machine is simple in construction and is made of various dimensions to suit the sizes of plates to be dealt with. It is specially adapted also for thin plates or taggers, the thinnest of which can be coated by it.

Plate II. illustrates one of the "half-circular" machines. The molten tin occupies the space in the lower part of the pot, the flux lying on the surface of the tin at the feeding end, where it may be confined in position by means of a rectangular box (constructed with four sides and without ends) inserted

partly below the surface of the metal. The palm-oil also lies on the surface of the tin, but at the delivery end, and is confined by the grease-box.

The plate is inserted by the tinman between the iron bars which form the guide GG', and passes through the flux into the molten metal, and is moved onward by a light iron rod in the hand of the tinman until it reaches the revolving rolls H, by which it is conveyed forward through the guides JJ' out of the tin and into the finishing rolls KK' revolving in the grease. The plate issuing from the rolls in a coated state is placed by the grease-boy in a rack for removal by the dipper.

Two grates are provided, that the temperature at each end of the pot may be separately controlled, a higher degree of heat being necessary at the feeding end than is desirable at the delivery or finishing end; this is further assisted by the narrow passage or neck which forms the connection between, and keeps apart, the two larger bodies of the metal. Plates of any length can be coated in this pot; the makers inform me they have satisfactorily coated experimentally one continuous length of plate 6 inches in width and 150 feet long.

Some of the half-circular machines are constructed with two distinct chambers. By this method the plate, after passing in a half-circular direction through the first bath of tin, is conducted by means of rolls over the top of the division into the second bath of metal, above the surface of which the finishing rolls are placed in the grease, the temperature of the separate baths being controlled by a fire for each.

The method of working is substantially the same in nearly all the machines, a tinman and a boy being employed to do all the work.

Plate III. illustrates another machine of the vertical type at work. This machine, the invention of Messrs. Rogers and Player, is unique in its operation, as dispensing with the services of the grease-boy—a tinman only being employed. The machine is of the vertical type, and consists of one tin pot, with a grease-pot over it, with one fire for the former and a small one for the latter, by which the necessary temperatures are maintained. The finishing rolls of this grease-pot are provided with troughs containing molten metal, in which the rolls

revolve with the object of washing or cleaning the plate of any scruff taken up from the tin pot. As the plates issue from the finishing rolls in the ordinary way they are automatically seized and removed to the rack to be dealt with by the dipper. This machine is known in the trade as the "iron man." The amount of tin required for coating by hand or by mechanical appliances is much the same. A box of 14×20 containing 112 sheets, and weighing 108 lbs. when finished, with a surface area of 435.5 square feet, may be coated with a good common coke finish with about 2 lbs. of tin, a heavier coating being applied for a charcoal finish. By means of the mechanical pots a saving is effected in the quantity of palm-oil used; hemp for brushes is entirely dispensed with, and a brighter plate is produced.

Dipping and Cleaning.—The plates on issuing from the grease-pots are either dipped by hand in fine bran, meal, or shudes, in two operations (each surface having to be treated), or are mechanically conveyed through the material placed in two troughs in such a way that both sides of the plates may be acted upon. When any grease which remained on the surface has thus been removed, the plates are rubbed by hand as previously described, or are passed through a nest of rolls covered with soft sheep-skins, which revolve at circumferential velocities varying to each other, by which the necessary rubbing is obtained, and the dust from the bran trough is removed. The operation being now complete, the plates are sorted, counted, weighed, and boxed ready for despatch from the works.

In dealing with the manufacture, no special reference has been made to terne plates, the method of their production being essentially the same as that of tin-plates, with the one exception that the coating consists of a mixture of tin and lead instead of pure tin. These plates are extensively used in the United States for roofing purposes, and it was to their production that the first efforts of the new American works were directed. The tests for tin-plates are ductility, strength, and colour, the two former properties being dependent on the quality of the steel employed and the care with which it is heated in the mill and annealing furnaces; and the latter, on the surface produced in the pickling, annealing, and cold-rolling processes, the thickness of the coating and the careful manipulation in the tinning pots.

The uses and requirements of tin-plates for household and packing purposes are too well known to need reference here; the material itself is convenient for transport, cheap, clean, and non-absorbent, is easily made up into any form, is air and water tight when soldered, and combines maximum of strength with minimum of weight and bulk. The rapid growth of population in our colonies and the advances of civilisation provide an ever-increasing demand for tin-plates, and although the door of our largest market has been permanently closed against us, there is reason to hope that there are still bright times in store for the Welsh industry.

DISCUSSION.

Sir JOHN JONES JENKINS, M.P., congratulated Mr. Hammond on the admirable way in which his paper had been prepared. He had first given an interesting historical account of the introduction of tin-plates into this country, and then a very graphic account of their manipulation, winding up by saying very glibly that the tin-plates, after having undergone the several operations he had detailed, were ready for despatch. The great difficulty now experienced, after getting the plates ready, was to know where to despatch them; and if Mr. Hammond had been able to give them in his paper any information on that point, he would have done the trade an immense amount of good. They must all have been struck, in listening to the paper, with the great growth that had taken place in the tin-plate industry from its first introduction into this country in 1673. It would be observed that this trade, like many others, seemed to be travelling from east to west. They had practically displaced the Saxons in the manufacture of tin-plates and taken their trade from them, and now they supplied nearly the whole of the Continent with tin-plates made in England; but in their turn they appeared to be losing the trade, for the Americans had stepped in as competitors, they having been the best customers the English manufacturers ever had. In fact, the consumption of tin-plates in that wonderful country had grown at such a rapid rate that the English makers practically lost their heads, thinking that no

other country, especially America, where the cost of labour was so great, would ever be able to compete with them. But the cunningness, the adaptability, and ingenuity of America succeeded in competing with England by making the consumers pay a heavy duty on all tin-plates introduced into the United States. That was undoubtedly a severe blow to this country. The statistics, so carefully prepared by Mr. Hammond, showed how the trade had increased up to 1891; the decrease had been going on ever since that period. They had, however, this little comfort. They were losing America—indeed, had lost the American trade entirely except the oil-canning trade, in which a rebate was allowed.

The Dingley Bill had practically put the last nail in their coffin so far as English tin-plates were concerned. The rebate was given in the case of plates which conveyed oil or fruit sent back to this country. But although there had been a constant decrease since 1891, chiefly due to the action of America, it was satisfactory to find that their exports to other countries had been increasing at a very rapid rate indeed. He would not enter into details, because there were other gentlemen who wished to speak on that and other subjects of interest to the Institute; but he might mention that the exports to Germany last year, as compared with the previous year, showed an increase of about 133 per cent. Although, however, the percentage of increase to other countries was large, it was a percentage on a much smaller quantity than was formerly shipped to America; hence the great difference in the returns. A short time ago he had made a calculation for the annual meeting of the Swansea Harbour Trustees, from which it appeared that if the increased shipments referred to went on at the same rate as during the last eighteen months, they would regain in eight years from the present time, if not earlier than that, the position they held in 1891.

He again congratulated Mr. Hammond on the attention he had bestowed upon his paper, which had made it so interesting to the members.

Mr. MAYBERY did not think that there was anything in the paper that needed discussion. It was a very lucid description

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of the manufacture of tin-plates, but there was nothing novel in it calling for debate. He agreed with Sir John Jones Jenkins that if Mr. Hammond could show them how to make profits out of tin-plates, he would be conferring a great boon upon the country. He had nothing further to say except to congratulate Mr. Hammond upon the admirable and lucid description given in the paper.

Mr. HAMMOND (in reply) thanked the members for their congratulations. He only wished that he could himself learn and show to others how to make the profit they all desired. The figures given by Sir John Jones Jenkins with reference to Germany were most interesting. Considering the increase in population and the many uses to which tin-plates were being applied, he hoped that they would very shortly see the trade again in a flourishing condition in this country.

The PRESIDENT said it only remained to him to move a hearty vote of thanks to Mr. Hammond for his able paper.

The vote of thanks was carried by acclamation.

The PRESIDENT said that Mr. J. S. De Benneville, who had already communicated several important scientific papers to the proceedings of the Institute, had favoured the members with an exhaustive paper on "Passive Iron." The author had been unable to come from Philadelphia to take part in the discussion, but the paper was one which ought to be read and studied before raising a discussion upon it: therefore, with the permission of the members, it would be taken as read, and the Secretary would be only too pleased to receive any communications on the subject. There was also another paper by Mr. Campbell on the important subject of "The Diffusion of Sulphides through Steel," which it had been suggested might be postponed and taken as read. The author was an eminent American chemist, who had done admirable work. He was sure the members would thank him for this his first contribution to their proceedings. They would be able to communicate to the Secretary any remarks they might desire to make.

PASSIVE IRON.

BY JAMES S. DE BENNEVILLE, PHILADELPHIA.

INTRODUCTORY.

To again revive the subject of the passive state of iron—a subject which has undergone such close and exhaustive investigation for nearly a hundred and twenty years—requires some sort of explanation as to why such revival is necessary or even justified. This, however, is afforded by the rise of a new theory of the structure of iron carbides, more particularly connected with steel, which seeks to explain certain changes in the physical properties of that substance as caused by allotropic change in the iron molecule, and not by chemical combination with carbon (or other elements), or by stresses and strains set up in the mass of metal and due solely to mechanical causes. Moreover, the setting-up of this allotropic theory brings the earlier stage of the investigation into close sympathy with its latest development, and the passage from the “altered” iron of the first observers, through the “passive” iron of the earlier modern chemistry, to the theory of allotropic change—all base their explanation on a new property acquired by the iron itself, markedly different from iron in its ordinary state, only affected by external conditions, and not admitting the reagent as sharing in the change. It is proposed in the present paper to follow the history of this question as it developed itself in the researches of successive investigators; to try and trace the connection between them as showing a progressive amplification of one central idea; and finally, to touch on the factor of this question, so far subordinated to its metallic phase—viz., the condition of the reagent (acid or salt solution) in which passivity was secured.

A sharp distinction is to be drawn between true passivity—in the sense of immunity from action under conditions where ordinarily it would occur—and such cases where no chemical action ensues at a certain degree of concentration but on further dilution action does take place. To the latter are to be added

such cases in which temperature or pressure are important factors, for reaction may not take place at the freezing point, although at 20° and under the same conditions inertia to the reagent entirely disappears, and likewise even at 20° reaction may be prevented if the external pressure be increased beyond a certain point. Such cases fall under dissociation phenomena. In cases of true passivity—using the term in its narrowest sense—temperature and pressure are still important factors, but they mark the extent of the change in widening their limits as influencing reaction. So passive iron can support a considerable rise of temperature without showing any sign of reaction, although ordinary iron at 20° and normal pressure would act energetically at once. The list of substances in which iron remains unaltered is a long one, and a number of them cause passivity in the sense of the narrower definition given above. As, however, all the phenomena are covered by two lines of investigation, the discussion of the results obtained by acting on iron with nitric acid of varying strength, and by the action of aqueous solutions of silver nitrate, involves all the distinctions existing between the two known forms of iron. Expressed in general terms, it is known that if a piece of bright iron be immersed in nitric acid of 1.40 specific gravity, at 20° and normal pressure, it will be found on removing it from such solution that it is not attacked if immersed in nitric acid of such strength as to attack it energetically under ordinary conditions; and, moreover, that iron so treated can no longer precipitate copper from solutions of the nitrate or sulphate. It is also known that concentrated aqueous solutions of silver nitrate are not decomposed by wrought iron or steel, whereas dilute solutions are decomposed. As to this latter point, it is claimed that previous immersion in the concentrated solutions renders iron passive when subsequently transferred to dilute solutions, and that the action of the silver salt solution differs according to the mechanical treatment to which the sample has been subjected. These two last points it is desirable to subject to examination, as on them depend to some extent the identification of an allotropic condition of iron in steel.

The explanation of the phenomenon known as the "passivity of iron in strong nitric acid" has been based on four separate

lines :—1. Chemical interference of further action of the acid—either by formation of an oxidation product which is insoluble in the acid, or a gaseous envelope; or in the case of silver solutions, by the formation of a protective coating of metallic silver, and so preventing further contact between the iron and the salt solution. 2. Mechanical interference—not derived from interaction between the acid and the metal. 3. Chemical change in the iron molecule itself—*i.e.* the iron is converted by the action of the acid, or silver salt solution, into an allotropic modification. 4. Physical change; the iron assuming a new magnetic or electric position. These four explanations do not present a direct line of experimental evidence. The earlier line of experiment was often revived—obviously from independent observation; but the particular observer of the time frequently represented in his work the accumulated experimental evidence and his final judgment as reviewer. In the frequent independence of action a general review of the subject might at this date find justification for grouping together the facts so obtained.

HISTORICAL.

The fact that iron was not attacked on immersion in strong nitric acid probably attracted attention at a very early date. The investigators of the iatro-chemical and earlier phlogistic period had, however, noticed the important part that water played in reactions, and the fact that nitric acid acted energetically when diluted with water clouded their ideas on the subject. Under such conditions—presence or absence of water as the important factor—Black * refers to the reaction between nitric acid and iron, and also between sulphuric acid and iron. In fact, as late as 1861 it was claimed that hydration of the acid was the important factor, for Peretti † attributed activity to the presence of two (OH) in the acid; whereas if but one (OH) was present, no action took place. As early as 1777 Wenzel started his researches on the neutralisation of acid by metals, and the reaction between iron and nitric acid could hardly have escaped him. To

* *Lectures*, American edition of 1806, vol. iii. pp. 168, 171.

† *Dell' azione chimica dell' acqua sopra gli i sali e sopra gli acidi* (Roma, 1861), cited by Ordway.

him* is attributed the first specific mention of this phenomenon in 1782. At this period the phlogistonists were making their stand against the new quantitative chemistry, and the controversy exciting the keenest interest on both sides, gave considerable impetus to the study of chemical reactions. Torbern Bergmann† examined the conditions under which metals were precipitated from solutions of their salts, and the peculiar behaviour of iron with aqueous solutions of silver nitrate attracted his attention. While he found that as a rule silver was not precipitated by iron from a strong nitric acid solution, yet in a few cases it was, and such precipitation he ascribed to the character of the iron acted on. As to strong neutral solutions of silver nitrate his statement is distinct, viz., that iron does not precipitate silver from such solutions.‡ The school of Lavoisier had advanced the dictum that the precipitating metal had a greater affinity for the oxygen of the acid or salt than the precipitated metal, and that therefore iron precipitated copper from its aqueous solutions, and in turn copper precipitated silver. The irregularities already noticed naturally attracted the attention of the phlogistonists as a weapon to be used against the new quantitative idea, and Kirwan was the next to mention the subject specifically in reference to the reactions between metallic iron and lead salts.§ It was at this point that the phenomenon was given its first regular examination, and in a manner so thorough that from the affinity point of view succeeding observers find themselves thoroughly anticipated. In 1790 James Keir|| read a paper before the Royal Society, "On the Action of Vitriolic Acid with Saltpetre—and of Solutions of Silver in Nitrous Acid—on Metals." In it he cites the work done by his predecessors Bergmann and Kirwan, and then goes thoroughly into the subject from its qualitative side. The principal details of this important paper establish the early history of this question. Keir showed that nitric acid solution of silver is at first precipitated by iron, but the action soon stops, silver redissolves, and the iron "remains

* By Ordway, from Wenzel's *Lehre von Verwandtschaft der Körper*, note, p. 108.

† Dissertation on "The Quantity of Phlogiston in Metals," *Opuscula Chimica et Physica*, vol. iii. p. 140.

‡ Translation of Cullen, vol. iii. p. 430.

§ "Precipitation of Metals," p. 244, "On Phlogiston" (London, 1789).

|| *Philosophical Transactions*, 1790, vol. lxxx. pp. 359-385.

bright;" fuming nitric acid and strong solutions of silver nitrate "alter" iron; such action is superficial, and removed by rubbing; on heating, action takes place; on diluting a silver solution, action takes place; iron so altered does not precipitate copper from the nitrate or sulphate; to the "two forms of iron" he gave the names "altered iron" and "fresh iron;" when "fresh" iron is brought in contact with "altered" iron, both are acted on at first, and then action ceases; "fresh" iron does not precipitate mixed saturated solutions of nitrate of copper and silver, or on addition of nitric acid; the explanation of the phenomenon is to be found, not in the solution, but in the condition of the iron. Thus thoroughly Keir covered his subject, and with him is found the first idea of a change in the condition of the iron itself, the existence of an "altered" or allotropic iron.

The general subject of metallic precipitations was made an object of investigation by Vauquelin,* Sylvester,† and more extensively by Fischer.‡ Also, in 1805, L. Thenard§ examined the action of nitric acid on iron, but mainly in reference to the formation of nitrates. In 1821 Pfaff|| examined the galvanic position of iron in a circuit with reference to a number of solutions. It was in 1827, however, that the passivity of iron was next touched upon with special reference to the abnormal property shown by the metal in its reactions with neutral and acid solutions of silver nitrate. Gustav Wetzlar¶ published the first of his papers on this subject, presenting a new side of the question, and basing his explanation of the phenomenon on an abnormal electric condition of the metal. Keir's results had dropped out of sight, and many of the phenomena discovered by him were rediscovered by Wetzlar. He distinguished the passivity induced by silver nitrate solutions from that induced by strong nitric acid, on the ground that the former reduced copper readily from its nitrate. As the iron wire remained passive even after gentle filing or scraping, he considered that a protective coating could

* *Allgemeines Journal der Chemie* (Scherers), 1799, vol. iii. p. 331.

† Gehlen's *Journal der Chemie und Physik*, 1806, vol. i. p. 539.

‡ Poggendorf's *Annalen*, 1825, vol. iv. p. 291.

§ *Annales de Chemie et Physique*, 1805, vol. lvi. p. 276.

|| Gilbert's *Annalen der Physik*, 1821, vol. lxi. p. 84; Kastner, *Archiv. Naturl.*, 1827, vol. xi. p. 273.

¶ Schweigger's *Journal der Chemie und Physik*, 1827, vol. xlix. p. 470; vol. l., pp. 88, 129; 1828, vol. liv. p. 324; 1829, vol. lvi. p. 207; 1830, vol. lviii. p. 302.

not account for the change of state. Plunged iron became negative, whereas before immersion it was positive. Wetzlar's results aroused much interest. Schweigger-Seidel* republished Keir's results with a commentary; and Th. Fechner,† disputing in part Wetzlar's results, reviewed the subject with special reference to the galvanic position of the iron in the silver nitrate solution, and the presence or absence of current. The action of silver nitrate solutions, neutral and acid, was also examined by Dumas.‡ In 1833 H. Braconnot§ published a paper which was mainly devoted to showing that the insolubility of salts in a chosen menstruum often resulted from the fact that the salt resulting from a double decomposition reaction was insoluble in the menstruum, and to the insolubility of nitrate of iron in nitric acid he attributed, tacitly, the passivity of iron in that acid. Braconnot's paper attracted the attention of Sir John W. Herschel,|| and he took the opportunity to corroborate the results and to add a number of details concerning the action of nitric acid on iron. Entirely independent of Wetzlar he also explained the phenomenon by the electric condition of the metal, and to such condition he gave the name of "prepared" iron. He also noticed the effect of shock, and noted the galvanic action caused by contact with other metals as influencing action or passivity; the "propagation" of activity from one end of an immersed sample until the whole was active; effect of concentration and intermittent action; the contact influence of platinum as causing passivity; the existence of a limiting point in the strength of the acid where passivity does not ensue under any conditions. As stated, his explanation lay "in a permanent electric state of the surface of the metal." Although Bergmann and also Keir had noticed difference in action as shown by different samples of iron, Herschel was the first to connect such variations with the treatment to which the iron or steel had been subjected, and he considered

* *Journal der Chemie und Physik*, 1828, vol. liii. p. 167.

† *Ibid.*, 1828, vol. liii. pp. 61, 141; 1830, vol. lix. p. 113.

‡ *Ibid.*, 1829, vol. lvii. p. 23; cited by Erdmann from *Annales de l'Industrie Française*, 1829. To Dumas, Senderens attributes the explanation that in neutral solutions of silver nitrate a coating of metallic silver prevents continued action on the iron.

§ *Annales de Chimie et Physique* (2), 1833, vol. lii. pp. 286-289. Instancing an observation of Pelouze that strong nitric acid with alcohol did not decompose potassium carbonate.

|| *Ibid.*, vol. liv. p. 87.

that annealed steel was not so readily attacked as hardened steel.

In 1836 Professor J. F. Daniell* published his experiments on the material for a battery of constant electromotive force, and which resulted in the well-known copper-zinc Daniell cell. In the course of these experiments, and from "theoretical speculations on its low equivalent," he substituted wrought-iron plates for the amalgamated zincs. Although the action with such an arrangement was almost *nil*, he found that on substituting such exposed plates for the platinum pole the action was energetic. Change in the iron, as affecting its relation to hydrogen and oxygen, suggested to him an explanation of the phenomenon as due "possibly to some difference of mechanical structure developed in this particular position." The same year Professor C. T. Schönbein† wrote to Faraday, calling his attention to certain phenomena which took place when iron was immersed in strong silver nitrate solution or in strong nitric acid. Many of the data noted by Keir were again brought to light. The additions he made to the controversy were both chemical and physical—viz., oxidation as a cause of passivity; a passive wire connected *outside of the liquid* with an active dissolving wire itself becomes active. Such action he attributed to the conversion of electrical energy, transmitted in the form of a current, into chemical energy; on making the iron the positive electrode, if it be used to close the circuit, the iron is not attacked; the influence of the aqueous solution on the evolution of oxygen at the positive iron. While granting the evident effect of superficial oxidation on the passivity of the iron, Schönbein prefers as an explanation the coexistence of an electrical state different from that of the normal metal. In transmitting this letter to Mr. Phillips, at that time editor of the *Philosophical Magazine*, Mr. Faraday‡ added a number of observations of his own. These were mainly devoted to establishing the electrical position of the iron so affected; and he called attention to the fact that on immersion at first the position of the iron was electro-negative,

* *Philosophical Transactions*, 1836, vol. cxxvi. p. 114.

† *London and Edinburgh Philosophical Magazine*, 1836, vol. ix. p. 53; vol. x. p. 75.

‡ See Schönbein, before cited; or Faraday's "Experimental Researches," vol. ii. pp. 234-247.

but afterwards changed, becoming electro-positive and passive. Faraday regarded the passivity of iron as due to its relation to oxygen under certain conditions. The formation of a coating of oxide, almost insoluble in nitric acid, gave protection against any further action of the acid; but if the position of the iron was changed, so that nitric oxide was carried to the iron, then de-oxidation took place and activity followed. His explanation, therefore, is based on the ground that iron has no attraction for oxygen under these conditions, and therefore does not act on the electrolyte. Only the superficial particles are oxidised, or in such relation to the oxygen of the electrolyte as to be equivalent to such an oxidation, and affinity for oxygen being satisfied and the superficial oxide being insoluble, the metallic surface escapes further attack. In the relation between iron and silver solutions he showed that only while the silver is precipitating is there any electric current. In this phenomenon of passive iron he saw plain evidence that voltaic action was due to chemical action and not to contact. At this time also (1836) Mousson* put forward a new explanation on the line of protective coatings. He observed that when activity preceded passivity, there was always an evolution of gas, and he considered that a coating of NO enveloped the immersed iron and prevented further contact with the liquid. Many of the electrical phenomena noted by Faraday were also noted by him, as also the effect of the relation to oxygen of the opposing metal in the circuit, *i.e.* whether oxidising or deoxidising. He also noted that on removing the acid by evaporation the passivity was lost. In 1837-38 Henry Noad† published the results obtained by the use of dilute acid ranging from 1.14 to 1.20 specific gravity. An important point noted by him was the influence the condition of the samples had on the results obtained; for if abraded or wet, passivity was induced only with difficulty. This influence of the "state of surface" over which the current passed appeared to him to explain the phenomenon, the condition being equivalent to oxidation. Also, in 1838 Thomas Andrews‡ studied the effect

* Poggendorf's *Annalen*, 1836, vol. xxxix. p. 330.

† *London and Edinburgh Philosophical Magazine*, 1837, (3) vol. x. p. 276; 1838, vol. xi. p. 48.

‡ *Ibid.*, 1838, (3) vol. xi. p. 305.

of intensity of current on passivity, such increase causing activity. In contact action he considered that activity depended on whether the electro-positive metal was oxidised by decomposition of water or of the acid itself, activity increasing with dilution. Also (1838), Professor Martens* examined critically Schönbein's results. In 1839 Buff† showed that the degree of passivity depended on the strength of acid used to bring it about, and also that passivity was destroyed by washing with water; and in 1845 Beetz,‡ reviewing the recent work on the subject, declared in favour of the oxide theory as the best explanation of the passive state of iron. At this point—although only touching the subject as a secondary object—can be mentioned E. Millon's§ work on the influence of traces of salts on solution, and Gay Lussac's criticism.

In 1859 Scheurer-Kestner|| again discussed the subject in connection with the formation of nitrates of iron. The particular point he touched on was as to the effect that the extent of saturation of the solution (in reference to its content of iron salt) in connection with the concentration of the acid had on passivity. But on treating one known product with acid of varying strength he found that action or inaction was independent of this factor. The next investigators were supporters of the oxide theory. Boutmy and Chateau¶ had noted the influence that oxidising or deoxidising substances had on the reaction and the loss of passivity by washing or rubbing, and the formation of nitrate crystals after long digestion gave support to this theory. Saint Edme** at this time made the distinction between steel and wrought iron the special object of his investigation, concluding that steel was made passive more readily, and remained so under conditions in which it was destroyed in the iron, both in reference to temperature and to the presence of hyponitrous acid. Peretti (1861) has been referred to in the Introduction. In 1862 Scheurer-

* *Bulletin de l'Academie Royale de Bruxelles*, 1838-42; and Poggendorf's *Annalen*, 1844, vol. lxi. p. 127.

† Liebig's *Annalen der Pharmacie*, vol. xxxii. pp. 1, 7; vol. xxxiv. pp. 129, 241; vol. xxxv. p. 1.

‡ Poggendorf's *Annalen*, vol. lxi. pp. 92, 234; vol. lxvii. p. 186.

§ *Comptes Rendus*, 1845, vol. xxi. p. 37.

|| *Annales de Chimie et Physique*, 1859, (3) vol. lv. p. 330.

¶ *Cosmos Revue des Sciences*, 1861, (1) vol. xix. p. 117.

** *Comptes Rendus*, 1861, vol. lii. p. 930.

Kestner* again contributed to the subject, and in 1863 Heldt† offered as an explanation the presence of insoluble nitrate of iron.

In 1865 John Ordway‡ published an important paper touching on passive iron, although the main object of his paper was the condition of formation of nitrates of iron. Several new ideas were introduced into the subject by him, but little or not at all taken into consideration up to this time. He called attention to the effect of temperature as modified by the concentration of the acid, and to the form of the metal used for experiment, viz., solid or drillings. Final action as to passivity he considered to depend on the *initial* temperature, and to be independent within certain limits of the subsequent temperature. Ordway considered that oxide or nitrate should dissolve within certain limits of dilution, and hence these explanations were unsatisfactory to him. His own explanation in its form is original. It connects Keir with the modern allotropists. Keir had advanced the theory of an altered iron. To allotropic iron Osmond attributes definite changes in the physical properties of certain classes of steel. Ordway ascribes the passive state of iron, brought about by immersion in strong nitric acid, "to molecular change induced by momentary electric action set up on first contact of the acid with the metal," and he compares this with the mechanical effects produced on tempering steel or on the induction of permanent magnetism.

In 1869 H. Cailletet§ showed the influence that pressure had on the solution of metals in acid, among them the action of nitric acid on iron. Also in this year Charles Tomlinson|| offered a mechanical explanation. In 1868,¶ in reference to the action of solids on solutions, he had defined certain solids as "nuclei-bodies having a stronger adhesion for the thing dissolved than for the liquid which dissolves it." Many reactions referred to "molecular change in solution" he considered to be dependent on the presence of foreign matter on their surfaces, especially of the

* *Bulletin de la Société Chimique de Paris*, 1862.

† Erdmann's *Journal für prak. Chem.*, vol. xc. p. 167.

‡ *American Journal of Science*, 1865, (2) vol. xl. p. 366.

§ *Comptes Rendus*, 1869, vol. lxviii. p. 395.

|| *Journal Chemical Society, Transactions*, 1869, vol. xxii. p. 125.

¶ *Proceedings of the Royal Society*, vol. xvi. p. 403; vol. xvii. p. 240; vol. xviii. p. 533; and *Phil. Mag.*, 1867.

1897.—ii.

nature of grease. He therefore introduced a new factor into the cause of such a phenomenon as passivity, viz., "catharism—or the influence of chemically clean surfaces." If the nucleus be chemically clean, there is no apparent difference between the adhesion of the gas on such surfaces and the liquid that holds the gas in solution. Strong nitric acid is a powerful "cathariser," and making an iron wire chemically clean, the acid adheres to it with force. Formation of nitrate is prevented, because nitrates of iron contain at least six equivalents of water of crystallisation, and this is not present in the stronger acid. In 1870 L. Schönn* attributed all electro-chemical action to galvanic connection of two metals in contact with a fluid; and in 1874 A. Renard† showed that the greater the dilution of the acid in which passivity was secured, the lower the temperature was at which action was finally brought about. He also showed that in weaker acid (1·31–1·28 specific gravity) passivity could primarily be induced by agitation and repeatedly pressing the iron against the side of the vessel. The same year (1874) P. de Regnon‡ called attention to the necessity of isolating the active and inactive parts of a wire, for passivity as a rule is to be reduced to a voltaic force carrying oxygen to iron and polarising it on the surface of the metal, and its destruction to voltaic force in the opposite direction, or to a current due to the polarisation of the oxygen, or by the absorption of the polarised gas by a body having affinity for oxygen; therefore, if the wire is not divided by an isolating medium, the acid vapours will place the upper portion in a state opposed to the passivity of the immersed portion. In 1879 and in 1880 L. Varenne§ published two papers on this subject, presenting some interesting data, and basing his explanation, as Mousson had done, on the protective action of a gaseous envelope. Noting the fact that activity could be caused, under certain conditions, by shock, by means of a magnet acting over a measured distance he determined the necessary amplitude of vibration to cause activity. Passivity he accounted for on the ground that, under all circumstances, it was

* Poggendorf's *Annalen*, 1871. Supplementary to vol. cxliv. Abstract, *Chemical News*.

† *Comptes Rendus*, 1874, vol. lxxix. p. 159.

‡ *Ibid.*, 1874, vol. lxxix. p. 299.

§ *Ibid.*, 1879, vol. lxxxix. p. 783; 1880, vol. xc. p. 998. Ramann noted the priority of Mousson.

preceded by chemical action, variable in duration according to concentration of the acid, and that the result of such action was the formation of an envelope of NO, which gas he identified by reaction with oxygen. The solubility of these gas-bubbles depends on the concentration of the acid, and by slowness of solution of the gas in acid near the limiting concentration he met the difficult question—for a chemical explanation—of intermittent action. Passivity, he showed, ceased under diminished pressure after a certain limit was passed. Varenne's results naturally attracted much attention, and E. Ramann* on examination restated and supported the oxide theory of Schönbein and Faraday. Ignition in hydrogen of finely divided and passive iron, previously dried in an indifferent gas, he states, yielded a considerable quantity of water. M. Bibart† also contested Varenne's results on the ground that oxidising agents aid and de-oxidising agents hinder the production of passivity.

The first detailed examination of the magnetic phenomena was made in 1887 by Nichols and Franklin.‡ The destruction of passivity they found to be influenced by the time during which previous exposure continued, by the presence of iron salts, by the strength of the acid, and by exposure to a magnetic field. The transition point was not abrupt, but final and complete loss of passivity was marked by explosive violence. The two first qualifications given above lowered the transition point, the third lowered it with increasing dilution, and the fourth also lowered it in proportion to the strength of acid. By use of a sensitive galvanometer they were able to show that two iron bars immersed in acid in such a magnetic field gave a permanent current in the circuit when connected with a wire. Such action they attributed to polarity, and, in the case of a single mass of iron, to local currents set up "between those parts of the metal in which magnetic forces are induced and the intermediate neutral parts of iron, the poles becoming as zinc to the other portion, and current flowing from the poles through the liquid to the neutral portion." In 1888 Saint Edme§ stated that nickel had a marked

* *Berichte*, 1881, vol. xiv. p. 1430. Abstract in *Journal of Iron and Steel Institute*, 1881, vol. ii. p. 708.

† *Nature*, 1881, vol. xxiv. p. 179.

‡ *American Journal of Science*, 1887, (3) vol. xxxiv. p. 419.

§ *Comptes Rendus*, 1888, vol. cvi. p. 1079.

effect in inducing passivity in iron, and this power he attributes to the presence of nitrogen. Nitrogenised iron he found to be readily made passive.

In 1889-90 Andrews* published his papers on the passive state of iron and steel. His experiments were directed toward determining whether passivity was a static condition, and whether the chemical composition and physical structure of the iron and steel had any influence on the passivity. The method used was the measurement, by means of a sensitive galvanometer introduced into the circuit, of the electromotive force set up. Passivity he found to be considerably modified by temperature alone. Passivity increases considerably with the strength of the nitric acid. Magnetisation he found to have slight influence on cold solutions, but this increased with rise in temperature. Magnetised steel had its transition point lowered as compared with unmagnetised steel. In general terms, rise in carbon increased the passivity, and wrought iron was generally found to be less passive than even low carbon steel. In 1891 Gautier and Charpy† again attacked the question from the chemical side. They found that iron is always attacked, no matter what concentration of acid is used. The action was either rapid with evolution of gas, or slow without evolution of gas, and this latter condition they identified with the passive state of iron. In 1896 J. B. Senderens‡ examined at length the action of aqueous solutions of silver nitrate on iron which had been subjected to varying mechanical treatment. Passivity he considered to be due to the conversion of the iron, by chemical or mechanical means, into an allotropic form. As the subject covered by his results forms part of the present paper, the discussion of them will be postponed to the succeeding sections.

* *Proceedings of the Royal Society*, 1888-90, vol. xlviii. p. 116; 1890-91, vol. xlix. pp. 120, 481.

† *Comptes Rendus*, 1891, vol. cxii. p. 1451.

‡ *Bulletin Société Chimique de Paris*, June 5, 1896, (3) vol. xv. p. 691; (3) 1897, vol. xvii. p. 279.

TABLE I.—*Composition of the Steel—in percentages.*

Sample.	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
A	0·22	0·011	0·005	...	0·36
B	0·20	0·020	0·004	0·009	0·35
C	0·24	0·012	0·004	0·012	0·37
D	0·36	0·076	...	0·014	0·40

Colour carbon (Eggertz method) in hardened samples : A = 0·132 per cent., B = 0·166 per cent., C = 0·139 per cent.

Descriptive Notes (accompanying the samples) from Mr. Kreuzpointner.

SAMPLE A.—(1) Annealed after cold-hammering; (2) cold-hammered until the piece split in two; (3) original piece before hammering; (4) hardened after cold-hammering.

SAMPLE B.—(1) Strained six times in the testing-machine to maximum load, then broken, then cold-hammered; (2) strained six times in the testing-machine to maximum load, then broken, then cold-hammered, then annealed; (3) hardened after cold-hammering; (4) original piece.

SAMPLE C.—(1) Strained in testing-machine seven times, then broken after cold-hammering; (2) strained in testing-machine seven times to maximum load, then broken after cold-hammering, then annealed; (3) strained seven times in testing-machine to maximum load, then broken after cold-hammering, then hardened.

SAMPLE D.—(1) Half-inch axle test-piece strained ten times to maximum load, then broken, then smashed flat cold; (2) strained ten times to maximum load, then broken, then smashed flat cold, then annealed; (3) strained ten times to maximum load, then broken, then smashed flat cold, then hardened; (4) head of axle test-piece, natural state.

TABLE II.—*Actions of Aqueous Solutions of Silver Nitrate on Annealed and on Cold-worked Mild Steel.*

Free Access of Air—Temperature 9°-20°. Form—Massive Fragments.

No.	Sample.	Description and Condition.	Remarks.	Weight of Steel Taken.	34 Grammes per L. Strong AgNO ₃ .		17 Grammes per L. Weak AgNO ₃ .	
					Immersed.	Transposed.	Immersed.	Decomposed.
1	A. { Boiler plate.	Cold-worked.	W, A, and M	5.1150	...	...	19th Jan.	...
2		"	W, A, and M	5.1598	...	...	19th Jan.	...
3		"	S, P—some silver deposited	5.4228	19th Jan.	21st Jan.	...	...
4		Annealed	W, A, and M	3.0960	...	...	9th Jan.	...
5		"	W, A, and M	1.0684	...	...	9th Jan.	...
6		"	S, P	3.8127	9th Jan.	11th Jan.	...	...
7	B. { Boiler plate.	Cold-worked.	S, P	2.8757	20th Oct.	24th Oct.	...	15th Dec.
8		"	W, A, and M	1.5554	...	...	2nd Dec.	9th Jan.
9		Annealed	S, P	3.7753	20th Oct.	24th Oct.	...	9th Jan.
10		Original piece	W, A, and M	2.3536	20th Oct.	24th Oct.	...	7th Dec.
11		Cold-worked.	S, P	1.4097	7th Aug.	10th Aug.	...	12th Sept.
12		"	W, A, and M	1.4000	...	...	11th Sept.	17th Oct.
13	C. { Boiler plate.	Annealed	W, A, and M	0.5407	8th Aug.	11th Aug.	...	12th Sept.
14		"	S, P	1.4075	9th Sept.	12th Sept.	...	17th Oct.
15		"	W, A, and M	0.8450	...	...	8th Sept.	24th Oct.
16		Cold-worked.	S, P—marked deposit of silver	4.1361	14th Dec.	16th Dec.	...	19th Jan.
17		"	W, A, and M	7.5879	...	...	14th Dec.	19th Jan.
18		"	S, P	9.7175	21st Dec.	23rd Dec.	...	19th Jan.
19	D. { Axle steel.	Annealed	W, A, and M	2.3800	14th Dec.	16th Dec.	...	11th Jan.
20		"	S, P	3.7016	...	...	14th Dec.	...
21		Grey pig iron	W, A—energetic action and rapid exhaustion of the silver solution	4.0000	5th Oct.	10th Oct.	Decomposed.	...
22		No. 3 grey charcoal pig	S—energetic action and rapid exhaustion of the silver solution	2.5996	7th Dec.	...	...	...
23		80 per cent. ferromanganese	S—energetic action and rapid exhaustion of the silver solution	1.5480	20th Oct.	26th Oct.	Decomposed.	...

Temperature 9°-20°, Form—Massive Fragments.

No.	Sample.	Description and Condition.	Remarks.	Weight of Steel Taken.	34 Grammes per L. Strong AgNO ₃ .		1.7 Grammes per L. Weak AgNO ₃ .	
					Immersed.	Transposed.	Immersed.	Solution Renewed.
24	A Boiler plate	Cold-worked.	W, A, and M	3.4356	...	...	22nd Jan.	3
25		"	W, A, P after first immersion	3.1828	...	...	22nd Jan.	3
26		"	S, P, marked deposit of silver	{ 3.3105	25th Jan.	27th Jan.	...	3
27		"	W, A, and M	2.0001	...	...	22nd Jan.	3
28		Annealed	W, A, and M.	9.1043	...	...	29th Jan.	3
29		"	W, A, and M.	7.9214	...	...	23rd Feb.	3
30		"	S, marked deposit of silver	{ 4.9880	23rd Feb.	26th Feb.	...	4
31		Cold-worked.	W, A, and M.	4.7036	...	...	26th Feb.	4
32		"	W, A, and M.	3.9867	...	...	26th Feb.	4
33		"	S, P	{ 5.2152	2nd Mar.	4th Mar.	...	4
34	B Boiler plate	Annealed	W, A, and M.	{ 5.5529	6th Mar.	8th Mar.	...	4
35		"	W, A, and M.	5.3953	...	...	5th Mar.	3
36		"	W, A, and M.	5.7241	...	...	5th Mar.	3
37		"	W, A, and M.	5.4332	...	...	5th Mar.	3
38		Cold-worked.	W, A, and M.	2.6556	...	...	9th Mar.	3
39		"	W, A, and M.	3.0098	...	...	9th Mar.	2
40		"	W, A, and M.	2.5728	...	...	9th Mar.	2
41		Annealed	W, A, and M.	4.0151	...	...	26th Feb.	4
42		"	W, A, and M.	2.5902	...	...	9th Mar.	2
43		"	S, P	{ 3.3650	9th Mar.	12th Mar.	...	2
44	D Axle steel	Cold-worked.	W, A, and M.	3.5419	...	...	16th Mar.	2
45		"	W, A, and M.	3.7744	...	...	16th Mar.	2
46		"	W, A, and M.	3.0695	...	...	16th Mar.	2
47		Annealed	W, A, and M.	2.8837	...	...	16th Mar.	2
48		"	W, A, and M.	2.9320	...	...	16th Mar.	2
49		"	W, A, and M.	3.1002	...	...	16th Mar.	2
50		"	S, P	{ 2.8011	16th Mar.	19th Mar.	...	2
50		"	W, A, and M.	...	...	...	...	2

P=passive, A=active, M=steady and continuous attack with deposition of silver throughout, S=strong solution, W=weak solution.

TABLE IIIb.—*Action of Aqueous Solutions of Silver Nitrate on Hardened Mild Steel. The Solutions previously Boiled, Cooled, and the Digestions made in Closed Flasks.*

Temperature 10°-20°. Form—Massive Fragments.

No.	Sample.	Description and Condition.	Remarks.	Weight of Steel Taken.	34 Grammes per L. Strong AgNO ₃ .		1.7 Grammes per L. Weak AgNO ₃ .	
					Immersed.	Transposed.	Immersed.	Solution Renewed.
51	A	Hardened	S, marked deposit of silver	7.8482	2nd Mar.	4th Mar.	...	4
52	Boiler plate	"	W, A, and M.	19.8612	6th Mar.	8th Mar.	...	3
53		"	S, marked deposit of silver					
54	B	"	W, A, and M.	7.1640	6th Mar.	8th Mar.	...	3
55		Hardened	W, A, and M.	16.4926	...	...	5th Mar.	3
56	Boiler plate	"	S, heavy deposit of silver, A.	42.9615	6th April	7th April	...	2
57		"	W, A, and M.	7.2327	...	...	6th April	2
58	O	"	W, A, and M.	12.1462	...	...	6th April	2
59		Hardened	S, P, as drillings.	...	3rd April	5th April	...	...
60	Boiler plate	"	S, P.	11.93 -	9th April	10th April	...	2
61		"	W, A, and M.	12.40 -	9th April	10th April	...	2
62	D	"	S, P, marked deposit of silver	18.27 -	...	...	9th April	2
63		Hardened	W, A, and M.	54 +	...	...	10th April	2
64	Axle	"	W, A, and M.	24 +	...	...	10th April	2
65		"	W, A, and M.	23.5 +	...	...	10th April	2
66	Steel	"	W, A, and M.	10.3 +	...	...	10th April	2
66		"	W, A, and M.	127.2 +	...	...	10th April	2

TABLE IV.—*Change in Specific Gravity of Mild Steel, after Mechanical Treatment and after Immersion in Strong Aqueous Solution (34 Grammes per Litre) of Silver Nitrate. Effect of Time on Immersion in Strong Nitric Acid.*

Sample.	Description and Condition.	Specific Gravity in Water.	Specific Gravity in Silver Nitrate.	Difference.	Exposure to Nitric Acid of 1.42 Specific Gravity.		
					45 Minutes.	4 Hours.	24 Hours.
A.	Original piece	7.753	...	...	9.035	8.359	8.299
"	Cold-worked	7.689	7.842†	0.153†	8.682	8.297	9.153
"	Annealed	7.726	7.755†	0.029†	...	...	...
B.	Original piece	7.798	7.845	0.047†	8.129	8.197	7.553
"	Cold-worked	7.819	7.834	0.015†	8.135	7.943	8.346
"	Annealed	7.865	7.868	0.003†	8.128	8.188	8.399
C.	Cold-worked	7.788	7.722†	0.064†	8.805	8.372	8.331
"	Annealed	7.838	7.815	0.023†	...	...	...
D.	Original piece	7.766	7.845*	0.079†	...	...	...
"	Cold-worked	7.741	7.762	0.021†	8.069	8.148	...
"	Annealed	7.752	7.747	0.005†	8.004	...	8.304

TABLE IVa.—*Change in Specific Gravity, due to Mechanical Treatment.*

Sample.	Class.	"Alpha Iron." Annealed.	"Alpha Iron." Original Piece.	"Gamma Iron." Cold-worked.
A.	Boiler plate	7.726	7.753	7.689
B.	"	7.865	7.798	7.819
C.	"	7.838	...	7.788
D.	Axle steel	7.752	7.766	7.741

TABLE V.—*Volume of Gas obtained by the Action of Dilute Sulphuric Acid on Passive Iron. Passivity induced by 45 Minutes' Exposure to Strong Nitric Acid. Measurements reduced to 0° and 760 mm. Mercury Pressure.*

Reaction $\text{Fe} + \text{H}_2\text{SO}_4 = \text{FeSO}_4 + \text{H}_2$ requires 399.4 c.c.

Sample.	Description and Condition.	Total Volume of Gas from one Gramme.	Oxygen percentage by		Remarks.
			Volume in c.c.	Weight.	
A	Cold-worked	163.9	0.89	0.00127	Drillings.
"	Annealed	189.7	1.82	0.00260	"
"	Hardened	120.3	0.42	0.00064	"
B	Cold-worked	160.8	1.08	0.00154	Solid piece.
"	Annealed	116.3	None	...	"
"	Hardened	112.8	1.12	0.00148	Drillings.
C	Cold-worked	165.2	None	...	Solid piece.
"	Hardened	118.2	0.80	0.00114	Drillings.
D	Annealed	109.0	...	...	"

Active in 10 per cent. solution of CuSO_4 . † Separation of silver. ‡ Solution of iron.

TABLE VI.—*Specific Gravities and Electrolytic Dissociation of Solutions used.*

Nitric Acid Solution— $\mu^\infty = 342.8$.					Silver Nitrate Solution— $\mu^\infty = 108$.				
v.	c.	μ .	α .	Specific Gravity.	v.	c.	μ .	α .	Specific Gravity.
c.c.									
64.1	982.6	21.0	0.06	1.420	...	...	...	...	...
93.4	674.6	49.0	0.14	1.325	...	...	...	...	...
107.4	586.4	64.7	0.18	1.290	...	...	...	...	...
111.4	565.4	67.7	0.19	1.280	...	...	...	...	...
132.0	477.2	81.6	0.24	1.240	...	...	...	...	...
150.6	418.3	103.9	0.30	1.215	...	...	...	...	...
164.7	382.4	112.8	0.32	1.195	...	...	...	...	...
225.9	278.8	154.7	0.45	1.145	...	...	...	...	...
253.1	248.6	166.8	0.48	1.130	...	...	...	...	...
281.2	224.0	172.3	0.50	1.120	...	...	...	...	...
301.7	208.8	195.3	0.57	1.115	...	...	...	...	...
500.0	125.6	220.2	0.64	1.065	...	...	...	...	...
Litres.					Litres.				
5.0	12.5	314.4	0.92	1.006	5.0	34.0	69.9	0.65	1.027
10.0	6.26	326.8	0.95	1.003	10.0	17.0	73.2	0.68	1.013
20.0	3.13	335.5	0.98	1.0005	...	...	...	...	...
40.0	1.56	340.9	0.99	1.0000*	...	...	...	...	...
...	...	...	...	...	50.0	3.4	87.5	0.81	1.002
...	...	...	...	...	100.0	1.7	90.7	0.84	1.0001
...	...	...	...	...	200.0	0.85	91.2	0.84	1.0000*
...	...	...	...	...	400.0	0.425	99.0	0.91	1.0000*
...	...	...	...	...	800.0	0.213	99.8	0.92	1.0000*
...	...	...	...	...	1600.0	0.107	99.4	0.92	1.0000*
...	...	...	...	...	3200.0	0.054	98.5	0.91	1.0000*

v = volume. c = grammes per litre of AgNO_3 or HNO_3 . μ = molecular conductivity.
 α = electrolytic dissociation.

PASSIVITY AND ALLOTROPY.

If the question is as to whether allotropy is the general cause of this phenomenon of the passive state of iron, and if this term is to be used in the present discussion, then a rigid definition of the term is necessary; and as here used it is understood to mean change in physical or chemical properties, or both, of an element necessarily without qualitative change in chemical composition. Although such a definition excludes the class of isomers, it does not exclude the existence of allotropic modification of an element as present in compounds of that element. Allotropy of an element, it is generally accepted, must be limited to two directions: *first*, increase or decrease in the number of atoms in the molecule; *second*,

change of arrangement of the atoms of a molecule containing at least three atoms—*i.e.* change in atomic linking. Of difference of degree in the valences of an atom capable of combining with more than one monovalent atom there is but little evidence, and that is extremely doubtful;* and of difference of degree in chemical valence it is to be remembered that such difference is strictly arithmetical and never geometrical. Of all the elements carbon gives the largest number of isomers in compounds, and yet no case is known which necessitates the assumption of difference in the chemical values of the carbon atom. Hypothetically such variation is possible, but practically it does not exist. In its very nature the disproof of such a proposition must be negative.† But increase or decrease in the *number* of atoms in the molecule grants stronger ground of belief for acceptance. For example, in the two forms of phosphorus—red and yellow—there is an instance of two substances differing in chemical and physical properties. Qualitatively their composition is the same; and, on heating, their vapour densities go through identical changes, following the rule of progressive simplification up to the limiting point. Whether, then, the ultimate composition be viewed from the standpoint of juxtaposition or interpenetration‡ of the final particles or atoms, the change from one form to the other, and to a gaseous form common to both—expansion or contraction—involves no contradiction.

Since, therefore, the question now under examination is, as to whether the passive state of iron comes under the heading of allotropic change of this element, the evidence must be mainly directed toward showing that this condition of iron is accompanied by properties characteristic of allotropy. If this can be shown, then it will be important to determine—*first*, whether the “altered” or allotropic iron of Keir is identical with the allotropic iron of Osmond; *second*, whether the change effected by the action of strong nitric acid and strong aqueous solutions of silver nitrate is the same in both cases; *third*, what effect the previous history of the iron has on the power of inducing passi-

* Lothar Meyer, “Modern Theories of Chemistry,” pp. 318–325.

† W. Nernst, “Theoretical Chemistry,” p. 253, translation of Palmer.

‡ See Sterry Hunt, “New Basis of Chemistry,” pp. 7 *et seq.*, on nature of the chemical process.

vity; and *fourth*, whether there can as yet be given an adequate explanation of the phenomenon known as the passive state of iron. As a matter of fact the determination of these minor questions is the means of determining the main question, viz., whether passive iron is an allotropic modification of that element. In connection with these points there were determined (1) the action of strong nitric acid—on the specific gravity and on the proportion of hydrogen obtained on solution of a known quantity of metal; (2) the action of solutions of silver nitrate as modified by heat treatment or mechanical treatment of the metal; (3) conductivity of the solutions used, as a means of their ionisation.

Silver Nitrate Solutions and Allotropy due to Mechanical Treatment.—Professor Senderens' results can, I think, fairly be stated as follows. Calling attention to the fact that strong aqueous solutions of silver nitrate—34 grammes of AgNO_3 per litre—do not attack, at ordinary temperature, iron of any kind, he considers that previous immersion in such solutions renders iron passive when transferred to solutions of such dilution as under ordinary conditions are readily reduced by iron. On direct immersion in such dilute solutions—3·4 grammes AgNO_3 per litre—annealed iron or steel is invariably attacked; but in the case of cold-worked iron the behaviour is erratic, in many cases such iron not being acted on, no matter what the dilution. The two points here to be emphasised are—(1) passivity as the invariable accompaniment of previous immersion in strong aqueous solution of silver nitrate, and (2) the action of cold-worked iron toward dilute solutions of silver nitrate, for in such cases he attributes inaction to an allotropic condition of iron. Later his researches were extended to irons and steels hardened by quenching from high temperature, and these hardened irons and steels he classes with the cold-worked metal.*

Analysis of Tables II., III., and III. B.—For the examination of this question Mr. Paul Kreuzpointner, of Altoona, very kindly prepared four sets of samples from boiler plate and axle steel, in which the carbon was the only metalloid present in appreciable quantity (Table I.—Composition). Two sets of experiments were made. In Table II. the silver solutions were freely exposed to air. In Tables III. and III. B. the cold silver solutions, pre-

* *Bulletin Société Chimique de Paris*, 1897, (3) vol. xvii. p. 279.

viously boiled to expel air, were contained in stoppered flasks. The Tables give the results obtained with assays of 23 annealed, 16 hardened, and 23 cold-worked samples from the steels, representing what Mr. Osmond has called Alpha and Beta iron, and what Mr. Howe has called (provisionally) Delta iron. In general terms it can be stated that previous boiling of the silver solutions and digestion without access of air leads to slower attack than when the solutions are not so treated. The general character of the results, however, has not been altered by the expulsion of any dissolved air. Taking up the first point mentioned—passivity as induced by contact with strong solution of silver nitrate—the results do not point to any energetic action in that direction, action in any way comparable with that of strong nitric acid. Of a total of 10 annealed samples so treated, 3, or 30 per cent., remained passive. With the more inert cold-worked samples (7), not one remained passive. That strong solution of silver nitrate has the power of inducing passivity is clearly shown by the instances in which it does so act, and as shown subsequently by the copper sulphate test; but on this point cold-worked and annealed iron give no evidence of difference in chemical structure. An important point to notice is the independence of the reaction in reference to the sample used. For with the same sample different results are obtained, such results not being dependent on the nature of the sample or on its condition—cold-worked or annealed. For example, A 3 cold-worked gives different results from A 6 annealed, as also D 18 cold-worked from D 19 annealed. On the other hand, C 13 and 14 annealed differ in the results obtained. With reference to the second point—evidence of allotropy in cold-worked iron—it can be at once stated that the action of the silver nitrate solution in some cases is not so energetic with cold-worked iron as with annealed metal. In the absence of other explanation this difference is to be attributed to difference in molecular structure, *i.e.* it implies allotropic change. At first view the distinction appears clearly to lie in chemical change as evidenced by change in chemical reaction. If, however, such reaction be examined more closely, objections to allotropy as a necessary explanation become evident. If cold-worked iron is an allotropic form of iron, and so shown to be by the difference

in its action toward dilute solutions of silver nitrate, its action should be consistent; for in making use of the nitric acid test or the copper sulphate test the criterion selected is *consistency*. The passivity of the iron is determined by its consistent reaction to these reagents, and if the reactions do not take place the existence of a passive state in the iron is denied. But cold-worked iron clearly fails at this point. The reaction is not constant for a given sample; for example, with B 7 and 8 and A 24 and 25. If B 8 and A 25 are truly representative of the reaction of Delta iron, it is difficult to understand the action of B 7 and A 24. Marking the fact that of cold-worked samples only 13 per cent. were passive under the conditions of allotropy laid down by Professor Senderens, it is difficult to explain inaction as a specific effect of cold-work. An important distinction is to be drawn between inconstancy of strong silver nitrate solutions as inducing passivity, and the apparently similar action of dilute solutions in only occasionally remaining inactive toward cold-worked iron. There are two distinct questions here presented—*first*, how far the action of strong solutions of silver nitrate can be compared with the action of strong nitric acid, and this can well be left until the action of the acid has been discussed; *second*, dilute silver nitrate solutions as a specific reaction for "Delta" iron, for, in fact, the variation in reaction may simply be a question which comes in another form under the first question.

Holding allotropy in abeyance, let us turn to the mechanical condition of the metal and examine as to whether the same inconsistency of reaction is found there. With strong solutions of silver nitrate it can be stated in general terms that all classes of steel do not reduce metallic silver. Why then does the occasional inaction of dilute solutions occur? But, it may also be asked, Why does strong silver nitrate solution rapidly attack cast iron and ferro-manganese and yet not act on annealed or cast steel? Does annealed or cast steel present a condition of iron which, as compared with its condition in cast iron, is also to be called allotropic, and is a hypothetical Epsilon iron to be called in as the only adequate explanation? For in the difference existing between annealed steel and cast iron the evidence brought forward can on the present grounds

be claimed to show chemical difference, and hence allotropy. Turning to the mechanical structure, admitted differences are found to exist between cast iron, with its looser texture, and the steels. Between annealed and cold-worked steels, on the one hand, and hardened steels is found difference in chemical condition of the carbon, and hence difference in physical structure—homogeneity *versus* heterogeneity—and this distinction increases up to a certain limit influenced by the content of carbon.* But between cold-worked and annealed steels no such physical or chemical difference can be called in. The distinction between those two classes lies in the mechanical treatment to which the metal has been subjected, and which, to the eye, effects change in the mechanical structure. Comparison can be made directly with the effect of such mechanical treatment upon metals other than iron. Mr. Howe† has discussed at length such changes as are brought about by cold-working, the same effect on the physical tests being obtained as in the case of iron, differences being shown in degree. For the purposes of the present paper, copper is an interesting example, for the cold-work effect does not show any marked effect on the chemical properties, and yet passivity can be brought about by appropriate means; that is, the effects of passivity and of mechanical treatment of this metal are obviously independent of each other. In the case of iron and solutions of nitrate of silver there is found a relation between mechanical structure—pig-iron *versus* steel—and the action of the reagent, specifically due to such mechanical structure. Such a relation may well exist between the more ultimate mechanical constituents of a steel which has been subjected to the mechanical treatment of cold-worked steel as compared with the unstressed condition of the annealed metal. A change in some respects analogous to the change existing in a copper wire when carrying the electric current. A change in the direction, not change in the composition of the constituent particles—speaking in the mechanical, or perhaps physical sense. It is well not to enter on such doubtful ground, but the variability of the reaction with dilute silver nitrate gives more ground for belief in such an

* Professor J. O. Arnold, *Minutes of Proceedings of Institution of Civil Engineers*, 1895-96, vol. cxxiii. p. 127.

† *Journal of the Iron and Steel Institute*, 1895, vol. ii. p. 266.

explanation than in that of allotropy, for which, as a specific reaction, it fails entirely.

The action of solutions of silver nitrate is more decided with hardened steels than with the same samples when annealed or cold-worked. The strong solution, as a rule, gave a decided deposit of silver, and in some cases activity proceeded to exhaustion of the silver solution. Passivity at times followed digestion with the strong solution. The action of the hardened steels gave little reason to associate them with the corresponding cold-worked samples.

Passivity is Induced by Strong Nitric Acid.—The essential feature of such passivity is that on transference to a dilute solution, which under ordinary conditions would attack it energetically, the iron remains unattacked. Moreover, such iron no longer precipitates copper from its sulphate or nitrate. Here one condition of allotropy is reached, viz., change in chemical properties without change in composition. It is important to determine what chemical change is effected in the iron, and what relation (if any) exists between change as caused by mechanical treatment and the allotropy caused by chemical action. One means of attacking the problem seemed to lie in the effect produced by the strong nitric acid on the specific gravities, and on the volume of hydrogen obtained from a given weight of metal. Allotropy, or change in chemical composition, could alter the specific gravity, and change in chemical composition would affect the volume of hydrogen. Passivity of iron due to a magnetic or electrical state would not cause any important change in either property. Change of volume due to allotropy, while decided in its features, is readily masked by chemical change in composition. Two factors are known in this particular case, and are to be taken into consideration: (1) solution of iron and consequent lowering of the specific gravity by too large a final divisor. Even with strong nitric acid, however, quantitative determination shows this factor to be of but little importance. But (2) increase in weight, through formation of oxide or absorption of gas by the metal, this would make the final divisor too small and hence raise the specific gravity beyond the true figure, and this factor will be found to be of great importance. The determination of the specific gravities after treatment with strong nitric acid is readily made;

for one of the definitions of passivity so induced, is, that the iron shall not be attacked by more dilute acid—within certain limits. The annoyances, therefore, due to the corrosive action of the strong acid can be avoided. In Table IV. are found the specific gravities of the steels in their original condition after immersion in strong aqueous silver nitrate solution and after immersion in strong nitric acid. With respect to this latter reagent the results are decided. The specific gravity has been raised—time of immersion being an irregular factor—and such increase must be attributed to allotropy or to the second factor mentioned above, viz., increase in weight due to the absorption of oxygen gas or to the formation of an oxide. That oxygen is present in iron so treated has been shown by Ramann, who, after drying finely divided passive iron in an atmosphere of an indifferent gas, obtained on ignition at red heat in hydrogen a considerable quantity of water. In another way his explanation can be shown to hold good. If iron so treated be dissolved in dilute sulphuric acid, it will be found that the gas obtained on such solution will show (1) oxygen gas (perhaps occluded) in the gas mixture, although in the untreated steels given in the Table no oxygen was found on such solution; and (2) a falling off in the hydrogen required by the reaction, $\text{Fe} + \text{H}_2\text{SO}_4 = \text{H}_2 + \text{FeSO}_4$. Oxidising effect on the ferrous salt present is also to be taken into account. The loss in hydrogen, however, accompanied by the *apparent* increase in specific gravity, shows clearly that the quantity of metallic iron has been reduced, and an increase in actual weight, due to the formation of oxide, has caused such change in the specific gravity.

The most striking change is that which takes place in the chemical properties of the iron. Iron treated as described can no longer replace copper in the aqueous solution of its sulphate. Is such behaviour to be attributed to allotropy, or to the presence of oxide of iron? Chemical reactions can be advanced to settle this question. As oxide of iron it could readily be understood that iron could not replace copper in its salts. If, however, the condition in nitric acid be examined, it is found that activity in dilute solutions can be brought about by shock, and the delicacy of the equilibrium often found to exist between the passive and active state of iron admits of no such relation existing as would

be required with oxide of iron. Also the fact that capacity for reaction is easily restored, and hence the reduction of the copper after prolonged standing, requires the presence of metallic iron in this passive state. Activity in acid of 1.25 specific gravity, and passivity in acid of 1.18 specific gravity, as effected purely by the method of treatment, likewise negative the effect of oxide of iron as an all-sufficient cause of passivity; for such activity can proceed to complete solution without any residue of insoluble oxide. The evidence, therefore, of the existence of an allotropic form of iron as brought about by contact with strong nitric acid is convincing in two important points—(1) such treatment has completed a chemical change in the metal as contrasted with its normal condition; and (2) this condition is unstable, inasmuch as slight change of external conditions unfavourable for its continuance readily brings about a return to the normal form. To compare it with other cases known among the metallic elements, it is external conditions which limit the allotropic change of tin. At normal temperature, or by such mechanical treatment as hammering, the grey pulverulent form is rapidly converted to the brilliant white lustrous condition. The modifications of metallic silver when subjected to mechanical or physical treatment are converted to the well-known white metal; and the purple or brown amorphous modifications of gold by melting or compression assume the well-known yellow form, with loss of all the properties which before such conversion distinguished it from this normal condition. That such change is brought about by—or at least is accompanied by—change in the electrical position of the iron, is also proved by the clearest of experimental investigations; but while the electric current may cause the allotropic form of iron to become for the time the stabler form, the chemical differences to be noted are due to the change in the iron itself, and only indirectly to the condition of the system. Copper is not reduced from its salts because the allotropic form of iron does not so react; but magnetised non-passive iron, or simply the presence of an electric current, can bring about no such changes as shown by substituting some other electrolyte for the strong oxidizer—nitric acid.

Silver Nitrate Solutions and Nitric Acid.—On the relation existing between the reactions of these two solutions with iron, and

the interpretation to be put on it, depends, to a large extent, the view to be taken as to the presence or absence of chemical proof of allotropic iron as caused by mechanical means. Is there a true difference between the effects caused by the action of nitric acid within certain limits of dilution and the effects caused by the action of aqueous solutions of silver nitrate within certain limits of dilution; or is the difference simply one of degree? It has already been stated that in some cases previous exposure to the action of strong solution of silver nitrate has brought about passivity in iron—as determined by the copper sulphate test. Also in some cases cold-worked iron when directly immersed in weak solution of silver nitrate has become passive, as shown by the same test. It has also been shown, however, that a strong objection to regarding the inertia as due to any specific effect of mechanical treatment lies in a lack of constancy of the reaction, which does not permit it to be accepted as the necessary concomitant of such mechanical treatment. It being admitted that passive iron results from contact with solutions—acid or silver salt—unless this action can be shown to be a matter of degree, indifferently, allotropy due to mechanical treatment or to the action of the silver salt could be claimed as the effective cause of the condition. But nitric acid causing passivity, and it is claimed here causing passivity through allotropy, brings about such condition in the iron without reference to any particular treatment to which it has been subjected, *i.e.* annealing, cold-working, or hardening. If then the reaction with silver nitrate falls under the same class as the reaction with nitric acid, coupling this with the uncertainty of the reaction with the silver salt as representing a specific effect due to mechanical treatment, to bring in the idea of allotropy due to cold work as the necessary and only sufficient explanation of the occasional inaction of dilute silver solution is superfluous. Such connection between the reaction of nitric acid and the reaction of solutions of silver nitrate on iron can be shown. Passivity can be induced by nitric acid within comparatively wide limits of dilution. Strong acid of 1.50 specific gravity induces passivity in iron; but so also can acid of 1.25 specific gravity. The fact, therefore, that solutions of nitrate of silver vary in their effect on iron can be readily understood in view of this same variation found in nitric acid.

The action of the salt unquestionably is not so energetic as that of the acid, and it is not to be expected. This is shown not only with strong as compared with weak solutions, but on comparing strong solution with strong solution, for the concentrated silver nitrate is not in any way to be compared with the strong nitric acid as far as their power of inducing passivity is concerned.* Failure to cause passivity can in the case of strong solutions of silver nitrate be attributed to the same delicacy of equilibrium that exists with nitric acid near the limiting point at which under no conditions of temperature or concentration passivity can be induced. The limits of dilution for silver nitrate solutions have been determined by Professor Senderens.† With more than 5.5 grammes of AgNO_3 per litre iron remains inactive, and it is only as the dilution approaches 3.4 grammes, or better, 1.7 grammes per litre, that reduction actively takes place. From the point of view just taken, the fact that dilute solutions of silver nitrate sometimes cause true passivity is of the same order as passivity caused by more dilute nitric acid. In this connection it is to be remembered that strong nitric acid, causing passivity in all classes of iron and steel, shows difference in degree in the energy of its action. For example, in passing from wrought iron to high carbon steels, and taking into consideration the mechanical treatment, and whether in rolled steel such treatment was done with hot or cold steel, it will be found that on these factors depends the electromotive force existing between two given steels.‡ To explain the inaction of cold-worked iron under these occasional instances by its mechanical condition, *i.e.* its texture, has at least the advantage over allotropy, *viz.* that the weak solution of silver nitrate is near its point of equilibrium, and under conditions in which the result may or may not give the passive condition. Consistency in reaction does not necessarily follow near the limiting point. But, if the reaction toward the silver solution is based on the then condition of the *iron*, a specific reaction for a certain existing allotropic form of that element, then consistency is necessary.

The Value of μ .—An interesting point depends on the deter-

* This difference was noticed by Wetzlar as far back as 1827.

† *Bulletin de la Société Chimique de Paris*, 1896, vol. xv. p. 692.

‡ T. B. Andrews, *loc. cit.*, vol. xlix. p. 481.

mination of the molecular conductivity for the limits within which passivity can be induced by nitric acid and by silver nitrate solutions. This would show what relation, if any, existed between activity and conductivity of the given reagent, and between the activity and conductivity of the two reagents as compared with each other; for in this latter case the value μ gives a direct means of comparison. The results, obtained by the method of Kohlrausch, for the solutions used, are given in the accompanying Table VI. Bearing in mind the fact that metals enter into solution in the form of positive ions, it will be seen that the influential factor in this case for the solution of the iron is the NO_3 ion. To this is to be added the power of the iron ions to drive the silver ions out of solution.* The difference between the electrolytic dissociation (α) of nitric acid and of silver nitrate solutions at once appears in the Table (VI.); and it is found that for equal dilution the dissociation of the acid is very much in excess of that of the silver salt, and that the inaction of silver solutions and their power of inducing passivity is to be compared with that of a stronger nitric acid than equivalent dilution requires. Moreover, on examining these values for μ , it will be found that as the concentration (c) reaches a dilution of 50 litres (3.4 grammes AgNO_3 per litre), the rate of increase of μ advances slowly, and whereas from 34 grammes to 3.4 grammes it covers 87.5 units, between 3.4 grammes and 0.2 grammes it only covers 11.0 units for the equivalent change in volume. Hence capability of inducing passivity disappears gradually, not suddenly, in this range. The low value of μ and α for nitric acid of a concentration with specific gravity 1.240+ has an interesting bearing on the inaction of such acid on iron in the absence of external application of heat. The question of the value of the two constituents of the acid or silver salt—viz., the basic and acid constituents—was proved in another manner by an important observation made by Schönbein and Faraday; that is, that this phenomenon depended on the relation existing in the system between iron and oxygen. This is simply a matter of experiment the results of which can be stated in the broadest terms, viz., that the presence of reducing agents destroys or

* See "Solution and Precipitation of Metals," as developed in Nernst's "Theoretical Chemistry," pp. 610-613.

prevents the passivity of iron. If a substance be present under such conditions that its oxidation takes place at the expense of the oxidiser, no passive state of iron can be brought about. Finally, the relative value of the physical and chemical tests of allotropy and of the condition of the system can now be stated. The violent changes brought about by the action of strong nitric acid are not to be expected with the silver nitrate solution. In the former the increase of weight due to the action of the acid entirely overshadows any change in specific gravity due to allotropy, for even in such a well-known case as that of tin there is only a change of one unit in the first decimal. In this case of allotropy of iron the physical test of change in specific gravity is of but little importance owing to secondary influences, and the tests which here must be relied on to prove the case for allotropy are the instability of the system and the change in chemical reaction without change in qualitative composition. It happens, however, that change in chemical reaction under such conditions would be the one test establishing a *prima facie* case of allotropy. It seems justifiable, therefore, to sum up the positive results of determinations of specific gravity, chemical reaction, and conductivity, as showing—(1) that chemical action takes place other than can be referred to allotropy, as is shown by increase in weight of the sample taken; (2) that chemical reaction shows that true allotropic change has taken place under conditions which it would be impossible to refer to the magnetic state or a protective coating as an explanation; and (3) that the difference between the action of strong nitric acid solutions and aqueous solutions of silver nitrate is one of degree, not of kind. The same relation accompanies their dilution.

PASSIVITY AND THE BETA-GAMMA IRON THEORY.

Since, therefore, the balance of chemical evidence lies in favour of the existence of an allotropic form of iron brought about by chemical reaction, it remains to consider the two modifications of iron likewise attributed to allotropic change, viz., one as brought about by physical treatment of the metal, the second as brought about by mechanical treatment of the metal. The difference between the two modifications lies not only in physical properties,

but in the relations found to exist between the iron and carbon, and as this metalloid approaches a limiting point. Mr. Osmond considers that if iron be heated to a temperature of nearly 1000° , it undergoes allotropic modification, to which he gives the name of Beta iron. This modification can be preserved if cooling be brought about by sudden quenching. Many elements present in commercial iron influence this phenomenon, either by retarding or promoting the change from the allotropic to the normal form. Properties peculiar to this Beta iron are regarded as the main factor in determining the physical properties. Mr. Howe calling attention to the fact that marked changes took place in the physical properties of cold-worked iron, and that such changes differed in degree and sometimes in direction from those obtained by quenching; therefore he provisionally established a distinction between quenched and cold-worked iron, giving to the latter the name of Delta iron.* The chemical distinction between the two forms is brought out clearly when carbon is present in the iron, for the change effected by quenching is accompanied by a radical change in the condition of the carbon—that is, change in chemical composition. In the case of Delta iron, however, no such change can be detected, and it is still more strictly limited to allotropic change. The question of allotropic change as brought about by physical influences (heat treatment) and mechanical influences (stresses producing permanent deformation) touches the subject of this paper on its chemical side. Change of state in the case of allotropic change as brought about by quenching from a high temperature is, from this point of view, supported by the fact that retardation on cooling occurs with practically pure iron—that is, evolution of heat evidences change in the condition of the system. Allotropic change brought about by purely mechanical treatment, such as cold-working, is supported by physical evidence alone.

As there is strong chemical evidence to show that the condition induced by immersion of iron in strong nitric acid is an allotropic change, it would seem important to establish some form of connection between such allotropic iron and the forms above mentioned, viz., Beta and Delta iron. That is to compare the

* Mr. Howe points out the possible identity of β and δ iron. Δ iron is here used as convenient to express the cold-work effect.

chemically caused allotropy of Keir with the physically caused or mechanically caused allotropy of Osmond and of Howe. Starting, therefore, with the iron factor in such compounds, and without reference to carbide of iron, the effect of chemical, physical, or mechanical treatment can be determined with iron which, after casting or on cooling from a high temperature, is allowed to reach the normal temperature so slowly that its various constituents are able to assume their most stable form. The condition of iron in such case—normal iron—has been called by Mr. Osmond, Alpha iron. If, now, this Alpha iron be subjected to the treatment as mentioned above, can any similarity be traced between the resultant forms? Or, for the purposes of the present paper, are the chemical reactions of Beta or Delta iron related to the chemical reactions of Keir's "altered" iron? Evidently not. It has been shown that the allotropic form of iron due to chemical treatment presents two peculiarities: (1) radical difference in chemical reactions as compared with normal iron; and (2) an instability so marked that when placed under unfavourable conditions it passes at once and rapidly into the normal form. This cannot be said of Beta or Delta iron. Beta and Delta iron readily reduce copper from its sulphate. But Beta and Delta iron can acquire all the properties of passive iron as readily as Alpha iron can acquire them; and the method of effecting this change in these two forms is the same as with Alpha iron, viz., immersion in strong nitric acid. Then, and then only, can Beta and Delta iron show this radical change in the nature of its iron factor, a capacity for change which is also shared with Alpha iron. But to apply the test of stability. Delta and Beta iron necessarily represent comparatively stable forms, and in this stability lies their practical use for engineering purposes. Their main limiting condition is temperature. The instability of Keir's "altered" iron is so marked that trifling changes in external conditions are followed by return to the normal condition. If, therefore, it be merely taken into consideration that Alpha iron has been subjected to varying treatment, it must be admitted that the effect produced by physical or mechanical treatment of such Alpha iron as compared with the effect produced by chemical treatment shows no evidence of similarity due to the same cause. The question therefore—Can Keir's "altered" iron and the "allotropic" iron of Osmond and

of Howe be shown to be related?—must here be answered in the negative.

It only remains to consider the relation of carbide of iron to this feature of the case. Without entering into the question as to whether the carbon of hardened steel be present as dissolved carbon (Osmond) or as diffused carbide (Arnold), it is important to ascertain what is the relation of carbon *in* iron to the chemical reactions which have been relied on as the main test of allotropy. The carbide of Abel and Müller, Fe_3C , is decomposed by solution of copper sulphate, and is but slightly attacked by strong or dilute solutions of silver nitrate. These are the reactions of the steels taken as a whole, and therefore presence or absence of carbide is not a modifying factor. Satisfactory evidence is thus afforded that the copper sulphate and silver nitrate reactions for allotropic iron apply to iron itself. This fact would reduce the evident relation existing between electromotive force set up and the carbon content of the steels simply to a proportion existing between carbide of iron and iron. The present data show that carbon *in* iron is not a modifying factor in allotropy of iron as caused by the chemical treatment of immersion in strong nitric acid or strong aqueous silver nitrate solutions.

CONCLUSION.

To conclude this examination of the passive state of iron, the theories advanced in explanation can be briefly stated as follows: *First*—and most important—is the oxide theory advanced by Faraday and Schönbein. The main objections to be urged against it are action by shock, complete solution on activity and hence failure to prove insolubility as the characteristic of the oxide so formed, recovered activity on long standing in copper sulphate solution. An explanation of the same order—Dumas' silver coating—is met by the same objections, and also the fact that solution of the silver is followed by passivity when nitric acid solutions of silver nitrate are used. *Second*—the insoluble nitrate explanation presented by Braconnot and afterwards advanced by Heldt does not satisfactorily meet the fact that passivity is actually conditioned, by definition, on its continuance in dilute solutions. *Third*—the gaseous theory of Mousson and

Varenne does not satisfactorily explain why limits of passivity on dilution are comparatively wide. Passivity can be maintained in solutions of 1.18 specific gravity, and activity can be brought about in solutions of 1.25 specific gravity. If then the activity is due to solution of the gaseous envelope at the proper dilution, this variation is not explained. A stronger objection lies in the action of oxidising agents which *condition* passivity. How then the presence of nitric oxide can be maintained under such conditions is difficult to understand, and, it can be added, such oxidation is advanced as evidence of the presence of NO. *Fourth*—against Tomlinson's mechanical theory can be advanced Cailletet's experiments on the effect of diminishing pressure; also action of strong nitric acid on heating, passivity induced by contact, effect of dilution of silver nitrate solutions, activity induced by shock, effect of position in the circuit on passivity. *Fifth*—the existence of a magnetic or electrical state different from the normal state of iron—advanced by Wetzlar and by Herschel, and supported by the recent experiments of Nichols and Franklin and of Andrews—does not in any way conflict with the existence of an allotropic condition of the iron. As an all-sufficient explanation, however, it can be said that the existence of such a magnetic or electrical state does not necessarily postulate change in chemical reaction as shown by using a non-oxidising electrolyte or by changing the relation of iron to oxygen in the circuit. *Sixth*—an "altered" or allotropic condition of the iron, proposed by James Keir, and by Professor Senderens in one of his interesting papers on metallic precipitations and Richter's law.

On the reaction with copper sulphate solution, and on the instability of the condition brought about by chemical treatment of the iron, must be based the evidence that the passive state of iron is due to allotropic change in the iron itself. In this paper the attempt has been made to show that previous heat treatment or mechanical treatment has not affected this reaction in the case of mild steel. Beta and Delta iron do not influence, nor can they be identified with iron "altered" by treatment with strong nitric acid. Such change in the iron includes not only allotropic change, but the formation of oxide as shown by the specific gravities and by the volume of hydrogen obtained on

solution in dilute sulphuric acid ; chemical reactions, however, necessitate the presence of allotropic iron. Passivity as induced by silver nitrate solutions differs in degree only from passivity as induced by strong nitric acid. It is believed that dilute solution of silver nitrate does not afford a specific reaction for the presence of cold-worked iron, because the action of this reagent is not constant for a given sample of iron ; for equivalent quantities the value μ of the acid being much greater than with the silver nitrate solutions, such solutions are properly to be compared with acid of greater concentration. At the limit at which activity takes place with the silver solutions, the value of μ is already approaching μ_{∞} , the change in the value of μ is gradual, and the limits in which passivity is caused by the solution comparatively wide.

In conclusion, I would express my indebtedness to Mr. Paul Kreuzpointner, through whose courtesy and kindness in preparing the samples the proper material was obtained.

CORRESPONDENCE.

Professor J. B. SENDERENS (Toulouse) wrote to say that the author's conclusions did not fundamentally differ from his own, but nevertheless there were some points on which they disagreed, and with regard to these he wished to offer some observations. In order to clear the ground for this discussion, it was very necessary to define the distinction which should be made between the inactivity and the passivity of iron. Inactive iron was that which was not attacked by certain solutions of nitric acid and of nitrate of silver; passive iron was that which, after immersion in similar solutions, had lost its power of reducing more dilute solutions. These definitions were followed in the subsequent communication.

I. *Inactive Iron*.—The experiments quoted by Mr. de Benneville, which were described in the *Bulletin de la Société Chimique de Paris*,* were made with iron wire varying from 0.5 millimetre (piano-forte wire) to 6 millimetres in diameter, both in the annealed and in the unannealed state. The unannealed wire was known as "clair et non recuit." The wires were carefully cleaned with glass or emery paper to remove all traces of oxide. None of the pieces served for two tests, and it was no exaggeration to say that more than five hundred specimens were used. The discrepancies which occurred especially at the beginning led to numerous repetitions of the experiment in search of the explanation of the variations, and it was thought that the reason was recognised.

(a.) *Solutions of silver nitrate*.—The author agreed with the writer that at ordinary temperatures neither annealed nor unannealed specimens reduced solutions containing $\frac{1}{10}$ th nitrate of silver or 34 grammes per litre. But if the dilution was increased to $\frac{1}{100}$ or to $\frac{1}{1000}$ of silver nitrate, or 3.4 to 1.7 grammes per litre, there was a difference of behaviour between annealed and unannealed iron. The former always caused a precipitate, whilst the second was more often inactive. Later on the writer showed† that, in the case of unannealed iron, the attack nearly always

* Vol. xv. p. 691, vol. xvii. p. 279.

† *Bulletin de la Société Chimique de Paris*, vol. xvii. p. 279.

started at the ends of the sample. To counteract this, the ends were coated with vaseline, and then the results showed remarkable uniformity. Annealed iron was always attacked as before, and its whole surface immediately covered with a black deposit of silver. Unannealed iron, on the contrary, would remain unchanged for an indefinite time in the solution, but if it was raised to a red heat and allowed to cool slowly, it became active and precipitated silver.

Annealed and unannealed wire could only differ on account of the work it received during its passage through the drawing dies. The deduction was accordingly made that the different behaviour was due to a difference in molecular structure, and that in these iron wires there were two allotropic states corresponding to the working and the annealing of the metal respectively.

These experiments could easily be repeated, and there was no doubt that the author would obtain the same results as with annealed iron if he made use of unannealed wire which was renewed at each experiment and carefully cleaned with glass or emery paper and was coated on its ends with vaseline. As regarded the influence of the vaseline, it would appear that the attack on the ends of unprotected and unannealed wire was due to the fact that the internal portions of the wire were in a different molecular state from that of the external layer. The latter had endured more stress during the manufacture, whilst the centre had not been worked to the same extent.

(b.) *Nitric acid*.—Annealed and unannealed wires also showed differences when immersed in nitric acid, but their behaviour was the inverse of what occurred in silver nitrate solutions, as the unannealed iron was most active. For fuller details the memoir* quoted above might be consulted.

On the whole, these facts appeared to show clearly that there was a difference of molecular structure between annealed and unannealed iron wire; that this difference arose from the working, and consequently that the metal occurred in two allotropic modifications, of which one was due to working and the other to annealing.

II. *Passive Iron*.—If the writer had properly grasped this

* *Bulletin de la Société Chimique de Paris*, vol. xv, p. 679.

interesting paper, the author dealt with the passivity of iron in solutions of silver nitrate and nitric acid, and the relationship between these two passivities.

(a.) *Passivity in silver nitrate solutions.*—On this point also they were not agreed. The writer, using annealed wires, had found that immersion in strong solutions nearly always induced passivity to weak solutions; but Mr. de Benneville found that that only occurred to the extent of 30 per cent. On that difference some comment was necessary. How was it that in the second table three specimens out of four remained passive, whilst in the third table all the specimens were active? That divergence could not be ascribed to the presence of air, as, by the author's own showing, the phenomena was not affected by the expulsion of air. Perhaps it might be due to the use in the second series of test-pieces which had already served in the first series of experiments. That explanation was tentatively advanced, but the difference in results was none the less singular. In addition, it would seem that the percentage itself was not beyond criticism. By multiplying the results obtained by ten, any possible error was also increased, and the conclusions would have had a firmer basis if the experiments had been increased.

The passivity of worked iron in silver nitrate solutions was nowhere mentioned by the author. Possibly it might be deduced from that that there existed an allotropic difference between annealed and worked iron. That absence of passivity was the more surprising as 13 per. cent. of the worked iron was inactive in dilute solutions even before immersion in stronger liquids. But that point was not insisted upon, as the writer himself had only experimented with annealed iron, and therefore could not bring evidence adduced from his own knowledge.

(b.) *Relation between passivity induced by nitrate of silver and by nitric acid.*—Mr. de Benneville had attempted to show that these two passivities were of the same kind, and that they only differed in amount. That was confirmed by the fact noted * by the writer, that passivity of iron in nitric acid might be brought about by first dipping it into nitrate of silver solutions and *vice versa*. There was, however, one objection. Unannealed iron, as had been

* *Bulletin de la Société Clinique de Paris*, vol. xv. p. 695.

shown above, was more active than annealed iron in nitric acid, and *vice versa* in silver nitrate. That diversity of behaviour was not altogether favourable to identity of cause.

As for the cause itself, was it not due, at least in part, to the production of an allotropic state? The writer thought that that was so, and the author was not far from holding the same opinion. But here intervened the above-mentioned distinctions between inactive and passive iron. The papers of the writer dealt especially with the inactivity and activity of annealed and unannealed iron, and with the two allotropic states which appeared to afford their explanation. In regard to the passivity of iron he was less decided, and it was by analogy that, amongst the causes of passivity, the opinion was advanced that allotropy might be introduced.

In conclusion, Mr. Senderens thought that some confusion might be due to his failure to exactly grasp the author's meaning, owing to its expression in a language different from his own, but he had no doubt that they could easily amicably settle any differences of opinion that existed between them.

ON THE
DIFFUSION OF SULPHIDES THROUGH STEEL.

BY E. D. CAMPBELL, ANN ARBOR, MICHIGAN.

IN 1893 the author read a paper on the diffusion of sulphide of iron through steel, before the American Institute of Mining Engineers. In this paper * five experiments were described, in which the rapidity with which the sulphide of iron used diffused through steel at a bright red heat was strikingly shown.

In these experiments, bars of soft steel 2·5 centimetres thick, 5 centimetres wide, and 15 centimetres long were used. The steel had the following composition: carbon, 0·17 per cent.; silicon, 0·00 per cent.; phosphorus, 0·11 per cent.; total sulphur, 0·074 per cent. The sulphide of iron used in the above experiments was a sample of the ordinary fused sulphide, used for the generation of hydrogen sulphide; it contained 20·62 per cent. of sulphur.

The first purpose of the experiments was to decide whether or not an unquestioned chemical compound could diffuse through steel at a bright red heat. The statement has been made that, because carbon will diffuse through steel at a bright red heat, the diffusing carbon must be in the condition of an element. If it were possible to get sulphide of iron to diffuse through steel, then the statement that, because carbon will diffuse, therefore the diffusing carbon is in the condition of an element, is without weight. The diffusing element may or may not be in a chemically combined form.

A brief description of two of the experiments above mentioned will suffice to show the extent to which the work was carried at that time. In one case a hole 12 millimetres in diameter and 30 millimetres deep was drilled in one edge of one of the bars above described. This hole was filled with 10 grammes of sulphide of iron, and closed by driving in a short steel plug, turned to accurately fit the hole. The bar, so prepared, was

* *Transactions of the American Institute of Mining Engineers*, vol. xxiii. p. 621.

then placed in a muffle furnace, brought to a bright red heat, and maintained at this temperature for four hours. An examination of the bar showed the hole to be nearly empty, except for a thin film. Drillings taken from the bar at various points, some within less than two millimetres of the original hole, showed no perceptible increase in the percentage of sulphur in the bar. The scale, formed by the oxidation of the iron at the temperature employed, showed portions containing 2.604 per cent. of sulphur. It was evident from this that the sulphide had diffused through the bar.

In the second case the bar was prepared like the first one, except that the hole containing the sulphide of iron, instead of being plugged, was left open, and the bar was so placed in a Hoskin's muffle furnace, that the interior of the hole could be observed through a small chimney in the top of the muffle. The bar was brought to a bright red heat, and the sulphide was noticed apparently to settle rapidly, almost as soon as thoroughly melted. When most of the sulphide had diffused, the bar was quickly withdrawn from the furnace and quenched in water; a distinct odour of sulphuretted hydrogen was perceived on quenching the bar. Drillings of the bar taken in the immediate vicinity of the hole showed no increase of sulphur above that originally present.

In the autumn of 1893 further experiments were undertaken to determine the conditions best suited to the diffusion. A different sample of sulphide of iron from that employed in the above experiments was used at this time. The results obtained were rather unexpected, for it was found that when a bar, prepared like those previously described, was heated, little or no diffusion took place. The temperatures to which the bar was heated, whether oxidising or reducing, were varied without apparently influencing the result. The work was again taken up in the fall of 1894, and experiments carried on for several months with apparently little or no better success than those of 1893. The identical bars used in the first experiments were employed, but the sulphide used failed to diffuse to any appreciable extent. It was not until the beginning of 1896 that the property of diffusing through steel was found to be peculiar to an oxysulphide of iron, instead of a normal sulphide. This peculiarity is proved and illustrated by the work described below.

A normal sulphide of iron, FeS , was prepared as follows: About 450 grammes of ordinary fused sulphide was placed in a clay crucible, contained in a Hoskin's gasoline furnace. The crucible containing the sulphide was covered with a crucible cover, perforated with a large hole, and on top of this cover was cemented a second inverted crucible, having a hole about 20 millimetres in diameter in the bottom. The second crucible extended above the top of the furnace, and through it sulphur could be introduced, without disturbing the crucible containing the molten sulphide. By this means it was easy to maintain the molten sulphide in an atmosphere of sulphur for any desired length of time. Experiments made by keeping the molten sulphide in an atmosphere of sulphur for varying lengths of time showed that all oxide present was reduced, and the composition became constant when normal ferrous sulphide was obtained.

The steel employed for the diffusion tests described in this work was kindly furnished by Mr. M. J. Moore, chemist, of the Illinois Steel Co., Joliet, Illinois. A Bessemer steel billet, having the following composition: carbon, 0.10 per cent.; phosphorus, 0.103 per cent.; manganese, 0.52 per cent.; sulphur, 0.091 per cent., was heated and drawn down under the hammer to a thickness of 2.5 centimetres and a width of 5 centimetres. This bar was then cut into pieces 5, 10, and 15 centimetres long, weighing about 500, 1000, and 1500 grammes respectively. The short pieces were the ones employed in the diffusion tests to be described. The holes for containing the sulphide were in all cases drilled vertically in the narrow side of the bar; the holes were in all cases 12 millimetres in diameter and 3 centimetres deep, thus leaving about 6 millimetres of metal on each side of the hole and 2 centimetres beneath. The holes were placed at varying distances from the ends of the bar, these distances being stated under each experiment. When a hole, after being filled with the sulphide, was plugged, this was done by accurately fitting a short tapered steel plug to the hole, and then driving it in with a hammer. In examining the interior of a plugged hole after a diffusion, it was almost always found necessary to drill out the plug, as it would be firmly welded in.

The furnace used for heating the bars was an assay muffle furnace, heated with gasoline. The muffle was 10 centimetres

high, 15 centimetres wide, and 25 centimetres long, provided at the back end with a small chimney 10 centimetres high, to increase the draught of air through the muffle, when an oxidising atmosphere was desired. Owing to the weight of the bars, and the thinness of the muffle bottom, it was found desirable to reinforce the latter with a heavy false bottom 1 centimetre thick. When an oxidising atmosphere was desired, the chimney was left open, and the front of the muffle loosely closed with the door. When a reducing atmosphere was wanted, the chimney was covered with a piece of mica, two or three large pieces of charcoal placed in the muffle, and the door closed and luted with fire-clay. Bars heated to a bright red heat for several hours in a muffle so prepared showed no signs of oxidation other than a slight blueing of the surface.

Experiment 1.—The hole in a bar 15 centimetres long was filled with 20 grammes of normal ferrous sulphide, FeS , and the bar so placed in the muffle that the open hole could be observed through the chimney. The muffle was then brought to a bright red heat, requiring thirty-five minutes. In fifteen minutes more the sulphide was observed to melt down; the temperature was maintained at a bright red, with an oxidising atmosphere, for one hour and twenty-five minutes longer. The flame was then turned out and the bar allowed to cool slowly. The sulphide was found to have simply melted down in the hole, but with no evidence of diffusion. In two or three other instances, where normal sulphide of iron was used in open or in closed holes, the same results were obtained.

Seeing, from Experiment 1, that the normal sulphide of iron, FeS , would not diffuse, we prepared a sub-sulphide in the following manner: 175 grammes of the normal ferrous sulphide was melted in a crucible, with the inverted crucible for a cover, arranged in the same manner as for making the normal sulphide. When the normal sulphide was perfectly liquid a little sulphur was added to insure complete reduction of any oxide that might be present; then very fine pure iron wire, tied up in little bundles of about 10 grammes each, was dropped in. At first the iron was very rapidly absorbed, but the absorption became slower, and, although the temperature was increased almost to a white heat, finally ceased, and apparently unattacked bundles of wire were

observed immersed in the liquid sulphide. The crucible was then drawn from the furnace, and the liquid sulphide poured into a flat iron mould. This sulphide was hard, brittle, and of a steel-grey colour, with a slight yellow tinge. The analysis of the sulphide showed the following composition:—

	Per Cent.
SiO ₂	0·10
Al ₂ O ₃	1·66
Fe	75·59
S	22·66

Assuming the sulphur and iron to be combined as a mixture of ferrous sulphide, FeS, and sub-sulphide, Fe₂S, the above would give:—

	Per Cent.
SiO ₂	0·10
Al ₂ O ₃	1·66
FeS	5·84
Fe ₂ S	92·41
Total	99·91

Experiment 2.—A bar 5 centimetres long was prepared with two holes, equally distant from the centre and ends. Each hole was filled with 12 grammes of the above sub-sulphide, and one of them plugged. The bar was placed in the furnace upon two supports, made by wrapping small pieces of iron 2·5 centimetres long, 6 millimetres wide, and 4 millimetres thick, with platinum foil. These supports were used to prevent any oxide formed during the operation from coming in contact with the muffle bottom, and also to prevent absorption by the muffle bottom of any diffused sulphide, experiments having shown that this absorption took place to a very marked degree. The bar was heated to a bright red heat, in an oxidising atmosphere, for two hours and fifteen minutes. The sulphide in the open hole had sunk very slightly, while that in the plugged hole showed no sign of diffusion.

Experiments 1 and 2 having shown that neither normal ferrous-sulphide, FeS, nor a subsulphide, approximately Fe₂S, would diffuse, we next made an oxysulphide in the following manner:—400 grammes of ordinary fused sulphide, such as is used for making hydrogen sulphide, and containing 23·6 per cent. of sulphur, was ground and intimately mixed with 13 per cent. of its weight of fine magnetic oxide of iron, Fe₃O₄. This

mixture was put into a fine grained clay crucible, and melted as quickly as possible. Although the crucible was not kept in the furnace more than five minutes after the sulphide had melted, the molten sulphide was observed to have penetrated in many places completely through the crucible. The crucible was withdrawn and the sulphide poured into a cold mould. Although the crucible was kept in the furnace so short a time after the sulphide was melted, it absorbed almost one-half its weight of the molten sulphide before the latter could be poured out. The oxysulphide obtained gave the following results on analysis:—

	Per Cent.
SiO ₂	0·81
Al ₂ O ₃	1·61
MnO	0·15
Fe	66·07
S	21·68
Total	90·32

Undetermined oxygen = 9·68 per cent. Combining the sulphur as ferrous-sulphide, FeS, and the remaining iron as ferrous-oxide, FeO, gives:—

	Per Cent.
SiO ₂	0·81
Al ₂ O ₃	1·61
MnO	0·15
FeS	59·62
FeO	36·16
Total	98·35

The above calculation would make the molecular ratio of ferrous-sulphide, FeS, to ferrous-oxide, FeO, in the oxysulphide, 4 : 2·97, or, practically, 4 : 3; and if the oxysulphide were a definite compound, its composition would be expressed by the formula Fe₇S₄O₃. Owing to the difficulty of obtaining the molten sulphide in a clay crucible, no attempt was made at this time to obtain the oxysulphide in a pure condition. The properties of the sulphide obtained above are illustrated by the following experiments:—

Experiment 3.—This was undertaken to show the rate and completeness of the diffusion of the above oxysulphide. A bar 5 centimetres long was used, with two holes equally distant from the centre and ends. Each hole was filled with 9·65 grammes of oxysulphide, and one of the holes tightly plugged, the other

being left open, so that the diffusion could be watched as it took place. The bar was supported upon the platinum supports, the open hole being directly beneath the chimney of the muffle.

9.65 grammes of the same oxysulphide was placed in a small covered porcelain crucible, which was then placed near the bar to determine whether or not the oxysulphide lost weight by heat alone. The furnace was lighted, and the temperature of the bar raised in an oxidising atmosphere. The bar attained a dull red heat in thirty minutes, and a full red in fifty minutes. At this time the sulphide in the open hole was observed to melt, and to commence to disappear rapidly: in from ten to fifteen seconds from the time the sulphide was observed to begin diffusing, the greater part of the sulphide had diffused through the steel, leaving only a small portion adhering to the sides of the hole, and a small piece, a few millimetres in diameter, in the bottom of the hole. The heat was turned off five minutes after this time, and the bar allowed to cool. On drilling into the plugged hole, the sulphide appeared to have diffused to practically the same extent as in the open hole. A rather thin scale of oxide was found on the surface of the bar, and this, on removal and analysis, showed 0.50 per cent. sulphur. It will thus be seen that the oxysulphide had diffused through the steel, and the greater part of the sulphur been oxidised by the air at the temperature at which the operation was conducted. The results of the first experiments described in 1893 proved that when that sulphide diffused through steel there was practically no retention of the sulphur by the metal. The oxysulphide in the porcelain crucible, placed near the bar of steel, melted in the crucible, but without change in weight.

Experiment 4.—This was planned to demonstrate that when diffusion of the oxysulphide takes place, the diffusion extends throughout the entire length of the bar, and not merely through the thin-walled metal between the holes and the sides of the bar. A bar 10 centimetres long was used, with the hole 12 millimetres from one end. In this hole was placed 12 grammes of oxysulphide of iron, the hole being left open. At the further end of the bar, a strip of sheet asbestos, about 3 centimetres wide, was so fastened that the ends of the strip were in contact with the top and bottom of the bar for a distance of about 2 centi-

metres. The asbestos was retained firmly in position by a wire passing around it. No portion of the asbestos was within less than 6 centimetres of the hole containing the oxysulphide, the object being to apply an absorbent material to two points of the bar, as far removed as possible from the diffusing oxysulphide. If the sulphide diffused as far as this material, it must have diffused through the entire bar. The bar, with the asbestos attached, was placed upon platinum supports, and the temperature brought to a bright red in an oxidising atmosphere. In forty-five minutes from the time of lighting the furnace, the bar had attained the full heat, the sulphide had melted and diffused, and the flame was turned out. The portions of the asbestos in contact with the bar, both at the top and at the bottom, were found to be black and saturated with oxide of iron, due to the oxidation of the diffused sulphide.

In order to study the behaviour of other sulphides than that of iron, cuprous sulphide was made by heating pure copper wire in a covered crucible, and treating as in the preparation of the normal sulphide of iron. When the copper was a full red, sulphur was added, and the temperature raised almost to a white heat, with frequent additions of sulphur for a little over two hours. In this way a nearly normal cuprous sulphide was obtained, as an analysis of the product showed 78.44 per cent. of copper, the theory for the normal sulphide, Cu_2S , being 79.8 per cent.

Experiment 5.—The bar used in this experiment was 5 centimetres long, with the hole equally distant from the ends, and of the usual size. In this was placed 12 grammes of cuprous sulphide, and the hole plugged. The bar, placed upon platinum supports, was kept at a bright red, in an oxidising atmosphere, for two hours and forty-five minutes. On drilling into the hole, the cuprous sulphide was found to have simply melted down, without diffusion. The scale on the outside of the bar was analysed, but found to contain no copper; no evidence of diffusion could be discovered.

Experiment 6.—This was made to determine whether or not the oxysulphide of iron, when mixed with cuprous sulphide, would diffuse, and if it did diffuse, whether cuprous sulphide would be carried along with it.

A bar 5 centimetres long was used, with two holes equally distant from the ends and centre. In one hole was placed 6 grammes of cuprous sulphide, together with 6 grammes of oxy-sulphide of iron, both being ground and mixed before introducing into the hole, which was then tightly plugged. In the parallel hole was firmly pressed 4 grammes of ignited asbestos, this hole also being plugged. The bar so prepared was raised on platinum supports, and brought in an oxidising atmosphere to a bright red heat, at which temperature it was kept for two hours. The scale, which was formed on the outside of the bar by oxidation, was much smoother and stronger than when iron alone was present. The scale was divided into three portions—that from the bottom, middle, and top of the bar weighing respectively 25, 19, and 24 grammes. On drilling into the first hole, the sulphides had apparently diffused, except for a lining of cuprous sulphide in the lower portion of the hole.

On opening the hole containing the asbestos, the latter was found to be soaked for 6–7 millimetres in depth, the lower portion of the asbestos being apparently unchanged. This altered portion of the asbestos was removed, weighed, and analysed. The bar was then weighed, and two holes drilled in it, one between the two original holes, but near the top; the drillings from these holes were mixed and analysed, to find the amount of copper retained by the bar. The distribution of the copper after the diffusion is best shown in the following table:—

	Weight. Grammes.	Per Cent. of Copper.	Weight of Contained Cu.
Bar	400	0·026	0·106
Asbestos	6	8·06	0·483
Top scale	24	2·47	0·593
Middle scale	19	1·94	0·368
Bottom scale	25	6·91	1·730
Total . . . . .	...	...	3·280

The 1·420 grammes of copper unaccounted for in the above table as the difference between the total copper added and that recovered, undoubtedly constituted the lining in the lower portion of the hole. A determination of the per cent. of sulphur (2·92) in the scale, showed the presence of 1·990 grammes, out of 2·600

grammes of sulphur originally present in the sulphides. The analysis of the asbestos containing diffused sulphide showed: iron, 24.28 per cent.; copper, 8.10 per cent.; sulphur, 9.98 per cent. If the iron shown in this had been derived from the oxysulphide diffusing without decomposition, and the copper from cuprous sulphide, also diffusing without change, then the theoretical percentage of sulphur which would have accompanied the amount of iron and copper shown by analysis, would have been 10.12 per cent., whereas that actually found was 9.98 per cent. The latter figure would go to prove almost conclusively that not only does the oxysulphide of iron diffuse unchanged, but that the cuprous sulphide passes also without decomposition through the steel.

Experiment 7.—This experiment, like No. 4, was intended to show that when diffusion of cuprous sulphide was brought about by means of the oxysulphide of iron, the diffusion also took place throughout the entire length of the bar. The bar used was 12 centimetres long, with a hole 12 millimetres from each end, thus leaving 5 centimetres of steel between the two holes. In one hole was placed 6 grammes of copper sulphide with 6 grammes of oxysulphide of iron, both ground and mixed, and the hole then plugged; the other hole was filled with ignited asbestos, and also plugged. The bar, raised upon platinum supports, was brought, in an oxidising atmosphere, to a bright red heat, and kept there for three hours. Upon opening the first hole, the sulphides were found to have almost completely diffused. The upper part of the asbestos was found to be converted into a hard, dark-coloured mass, weighing 1.2 grammes and containing 0.276 grammes of copper, thus demonstrating the distance to which the copper sulphide may be carried by the diffusing oxysulphide of iron.

On sawing a vertical section through the hole originally containing the sulphides, it was found to be lined in the lower portion with cuprous sulphide, Cu_2S . On polishing this section, etching, and examining microscopically, the outline of the original hole appeared to be perfectly sharp, and there was no evidence that the steel had been attacked by the sulphides which must have entered the metal at this point.

The next sulphide operated upon was that of nickel. This

was prepared by heating pure nickel wire under the same conditions as those used in making cuprous sulphide. The metal was heated and kept in an atmosphere of sulphur until it had taken up all the sulphur with which it would combine. Several experiments proved that when nickel is heated with sulphur, and the sulphide produced kept melted in an atmosphere of sulphur, the sulphide Ni_4S_3 is the result.

Experiment 8.—To determine whether nickel sulphide, like cuprous sulphide, could be made to diffuse by mixing it with oxysulphide of iron. The bar used was 5 centimetres long, prepared with two holes, as in Experiment 6, one filled with asbestos and plugged, the other with 6 grammes of nickel sulphide and 6 grammes of oxysulphide of iron, both ground and mixed before being placed in the hole, which was afterwards plugged. The bar, upon platinum supports, was heated in the usual manner, and kept at a bright red for two hours and fifty minutes. On drilling into the hole, practically all of the nickel sulphide seemed to have remained in it, after melting down. The scale formed on the bar was divided into two parts,—that from the lower and that from the upper part of the bar—the scale from the lower portion weighing 24 grammes, and showing 0.26 per cent. of nickel or 0.023 grammes; thus it will be seen that although there was 4.26 grammes of nickel in the nickel sulphide used, only 0.085 grammes diffused through the bar. The asbestos showed no change in appearance.

The above experiments were selected from forty diffusion tests, extending over a period of about ten months, distributed in three or four intervals during the past three years. The following possible explanation of the observed phenomena might be offered. The oxysulphide being an extremely mobile liquid at the temperature at which the experiments were performed, would readily be absorbed by any porous body. The rapidity of its absorption by the crucible, while being made, shows this. If steel is at all porous at a bright red heat, then the oxysulphide would diffuse through these pores and be drawn rapidly into any porous absorbent material, such as asbestos, or scale from the superficial oxidation of the bar. The retention of so small an amount of copper by the bar after diffusion takes place, shows that although pores may exist in the steel, their volume is extremely minute,

compared with that of the metal. The tendency of the diffusing sulphide to accumulate toward the lower part of the bar, as shown in Experiment 6, would show the influence of gravity on the diffusing sulphide, and that it diffuses in a liquid and not gaseous form.

The fact that pure cuprous sulphide will not diffuse, although a mixture of pure cuprous sulphide and oxysulphide of iron will do so, can only be explained by the assumption that pure cuprous sulphide is not sufficiently mobile, when liquid, to enter the extremely fine pores in the steel, but that its mobility is increased sufficiently by diluting with the extremely mobile oxysulphide of iron to enable absorption, and diffusion through the bar, to take place.

The failure of the greater part of the nickel sulphide, Ni_3S_2 , to diffuse, even when mixed with oxysulphide of iron, would clearly show the greater difficulty of obtaining this body in a sufficiently finely divided state to enter the pores of the steel.

The above experiments were made in the spring of 1896; and, in the following autumn, the work was again taken up, the object being to produce, if possible, the oxysulphide in a pure condition.

An examination of the analysis of the oxysulphide artificially produced, gave a ratio $\text{FeS} : \text{FeO}$ of practically 4 : 3. To determine whether this were accidental or not, we produced another oxysulphide, having, as will be shown below, a composition almost identical with the above. This was done by mixing ordinary sulphide of iron, containing 26.3 per cent. of sulphur, with 40 per cent. of its weight of precipitated magnetic oxide of iron, Fe_3O_4 , both materials being ground before mixing. A large porcelain crucible, wrapped in asbestos to prevent cracking, and supported in a fire-clay ring, was used for containing the sulphides. This crucible, filled with the mixture of sulphide and oxide, was placed in a Hoskin's furnace, and heated until the mixture was melted, a cover being kept on the crucible during the operation. When the mixture which was first introduced had melted and settled, fresh portions were added, until the crucible was full of molten sulphide. After keeping the sulphide in the molten condition for about ten minutes, the furnace was turned out, and the crucible allowed to cool. On cooling, the button was found to have the shape of the crucible, the latter having been broken

into small fragments by the expansion of the oxysulphide on solidifying. A clean button, weighing 1035 grammes, was obtained. On breaking open this button, the upper two-thirds was found to have a distinctly crystalline structure, many individual faces, some of them 7 millimetres in length, were perceptible, although no entire crystals could be found: 635 grammes of the distinctly crystalline oxysulphide was separated, the remaining 400 grammes being compact, and showing only slight evidence of crystalline character. Although the entire 635 grammes seemed to be homogeneous, the portion used for studying the properties was obtained by selecting pieces having one or more crystalline faces. This oxysulphide is of a steel-grey colour, with a blue tinge. The sp. gr. is 4.834. It is quite friable, grinding easily to a fine powder.

The amount of oxides, other than that of iron, was determined as follows:—A weighed sample of the oxysulphide, placed in a tared platinum dish, was dissolved in HNO_3 . After solution and evaporation to dryness, the nitrates were converted to oxides by gradually heating the dish to a full red heat in a muffle furnace. From the total weight of oxides thus obtained was deducted the ferric oxide, Fe_2O_3 , calculated from a volumetric determination of the iron. The analysis of the oxysulphide gave the following results:—

	Per Cent.
Oxides, other than iron	4.22
Iron	65.88
Sulphur	21.30
Oxygen (by diff.)	8.60
	<hr/> 100.00

The oxides, other than iron, consisted principally of SiO_2 , Al_2O_3 , and K_2O , derived from the porcelain in which the sulphide was melted and from impurities in the precipitated Fe_3O_4 .

On treatment with hot HCl (1.1) the sample goes completely into solution, except a small residue of SiO_2 . All of the sulphur passes over as H_2S , as was shown by absorption of the evolved gas in potassium hydrate and subsequent determination, after oxidation, as BaSO_4 . All of the iron was found by titration to exist in the solution as FeCl_2 . The fact that all of the sulphur passes over as H_2S , and that all of the iron exists in the solution as FeCl_2 , would prove that all of the iron must have existed in the oxy-

sulphide in the ferrous condition. For, had there been any ferric iron originally present, part of the sulphur must have been oxidised by the ferric iron to prove sulphur, which would have remained behind, suspended in the solution.

If we deduct from the total per cent. of iron 65.88, the amount of iron, 37.19, necessary to form FeS with the sulphur present, we obtain 28.68 per cent. This would require, theoretically, 8.20 per cent. of oxygen to form FeO, whereas the amount obtained by difference, in the above analysis, is 8.60 per cent. Calculating all of the sulphur as FeS, and the remainder of the iron as FeO, the above analysis would become:—

	Per Cent.
Oxides, other than iron	4.22
FeS	58.49
FeO	36.89
	<hr/>
	99.60

The molecular ratio between FeS and FeO in the above is 4 : 3.085, again practically, 4 : 3, and the composition, as in the earlier diffusing oxysulphide, would be expressed by the formula $\text{Fe}_7\text{S}_4\text{O}_3$. The solution of this oxysulphide takes place according to the equation:— $\text{Fe}_7\text{S}_4\text{O}_3 + 14\text{HCl} = 7\text{FeCl}_2 + 4\text{H}_2\text{S} + 3\text{H}_2\text{O}$. The non-crystalline portion, obtained with the above crystalline oxysulphide, contained 20.70 per cent. of sulphur.

A second crystalline oxysulphide was obtained by melting down, under similar conditions, a mixture containing a smaller proportion of the sulphide. The yield of crystalline oxysulphide was only about one-third, about two-thirds being non-crystalline. Analysis showed the crystalline portion to contain, iron, 65.21 per cent.; sulphur, 21.21 per cent.; while the non-crystalline portion gave, iron, 65.80 per cent., with only 18.96 per cent. of sulphur. This would indicate the tendency of a distinct chemical compound to crystallise out.

Having thus obtained a crystalline oxysulphide of practically the same composition as the diffusing oxysulphide used in the earlier experiments, we expected it to diffuse with equal facility. On testing the diffusibility in the manner described in Experiment 3, however, the author was surprised to find that there was little or no diffusion, the sulphide simply melting down in the hole. Further experiments were then undertaken to obtain, if possible,

a pure diffusing oxysulphide, but although more than forty different sulphides were made, none was obtained which would diffuse completely, although partial diffusion was obtained in many cases. The extent to which diffusion took place, varied in these latter samples from nothing to five-sixths of the sulphide. The exact conditions, whether chemical or physical, governing the formation of the diffusing oxysulphide, have not as yet been determined, although the author hopes to continue the work later on, and to make further attempts to solve this question.

He would here acknowledge his indebtedness to his several assistants, Messrs. W. G. Wallace, Firman Thompson, E. B. Hart, and Armand Miller, for the care with which they have conducted the laboratory work in the above experiments.

CORRESPONDENCE.

Mr. J. E. STEAD, Member of Council, had obtained a bar of very pure basic steel and bored several holes at equal distances apart along its length. Into these holes varying mixtures of pure sulphide and oxysulphide of iron were placed. The bar was then placed in a furnace and heated in order to ascertain whether diffusion would follow, but in no case did he obtain satisfactory evidence that the sulphides had passed through the steel. His results negated the experimental results of Mr. Campbell; but as it would appear that very slight variations in the conditions of working, even in Mr. Campbell's laboratory, gave very different results, it was possible that the necessary conditions were not obtained at Middlesbrough. It was difficult, however, to conceive that diffusion would take place through solid steel without some of the diffusate being left *en route* to the exterior. In all other cases in which diffusion occurred of solids in solids, or liquids in solids, or liquids in liquids, some of the element diffusing had been left in the mass; and it was his opinion, therefore, that the experiments of Mr. Campbell required most careful verification before they could be accepted.

The meeting then adjourned.

The proceedings were resumed on Wednesday, August 4, Mr. EDWARD P. MARTIN, President, again occupying the chair.

The following paper was read:—

THERMO-CHEMICAL STUDY OF THE REFINING OF IRON.

By HONORÉ PONTIÈRE, PROFESSOR AT THE UNIVERSITY OF LOUVAIN.

I. PRELIMINARY REMARKS.

THE *Journal of the Iron and Steel Institute* contains two papers on the application of thermo-chemistry to the pneumatic refining of iron, one in 1889 by Mr. Pourcel on the "Applications of Thermal Chemistry to Metallurgical Reactions," and one in 1895 by Mr. Hartley on the "Thermo-Chemistry of the Bessemer Process." The object of the present paper is to explain, as far as possible, from existing analytical and thermo-chemical data the phenomena which occur during a blow in a converter.

The author is not oblivious of the boldness of such an attempt, and distinctly disclaims any idea of rigorous exactitude. On the one hand, the present ignorance of the heats of formation of silicates deprives us of an important element in the calculation; and on the other hand, the complexity of the metal under treatment and the imperfect knowledge possessed concerning the compounds in which the different elements exist, have necessitated hypotheses which may not be altogether in accordance with facts. Thus no attempt has been made to deal with double compounds, such as silico-carbides, the double carbides of iron and manganese, &c., which are difficult to estimate, and of which the heat of formation is unknown.

Even if the conclusions arrived at in this study are in harmony with the facts, there is still some uncertainty as to the validity of the argument; and to this reservation the author would add the wish that analysis may soon give some method of determining the exact composition of pig iron, and that the tables of thermal equivalents may contain all the data necessary for dealing with this interesting question.

II. ANALYSIS OF IRON TREATED.

A white iron of the following composition is assumed:—

Silicon.	Manganese.	Carbon.	Phosphorus.	Sulphur.	Iron.	Total.
1.00	1.50	3.50	1.40	0.01	92.59	100.00

This metal is suitable for treatment by the basic Bessemer process.

III. CONDITIONS UNDER WHICH THE ELEMENTS EXIST IN THE IRON.

On account of the great heat of formation of the silicides, carbides, phosphides, and sulphides of manganese,* this metal exists entirely as those four compounds in the bath. It may be considered as certain that none of the manganese exists in a free state.

The phosphide of manganese is present in negligible quantities. The iron, which forms in pig iron endothermic compounds with carbon, silicon, and sulphur, or at least compounds which evolve but very little heat during their formation, gives a phosphide of which the heat of formation is comparable with that due to phosphide of manganese.† It may therefore be concluded that the phosphorus of the metal is divided between the iron and the manganese approximately in proportion to their mass, and that in the case under consideration this metalloid is practically only present in the state of phosphide of iron. The iron is only combined with the balance of the silicon, carbon, and sulphur which the manganese is insufficient to absorb.

IV. CONSTITUENTS OF THE IRON.

The known carbides of manganese are Mn_3C , MnC_2 , Mn_2C_3 . In the pig, this metal combines with the greatest amount possible of carbon, since the carbide of manganese is the most stable of the compounds which can be formed. The formula MnC_2 is thus arrived at. For the other compounds the known formulæ Mn_2Si_2 , MnS , Mn_3P_2 , are adopted. As the iron is present in great excess in the bath, in all probability the ferrous compounds present are those corresponding to known formulæ containing

* According to Troost and Hautefeuille in their "Etude calorimétrique sur les carbures, les siliciures, et les borures de fer et de manganèse," *Annales de Chimie et de Physique*, 5th series, vol. ix., 1876.

† *Loc. cit.*

the largest possible amount of metal, that is, Fe_3C , FeSi , Fe_3P , FeS .*

In default of knowledge of the possible and even probable combinations of the eight constituents, excluding the free iron, it is assumed, as was stated in the opening paragraph, that the eight compounds exist in a free state in the metal, and not combined amongst themselves to form double silicides or carbides of iron and manganese, or silico-carbides of one or other of the two metals, &c. It is considered that this hypothesis will not detract in any way from the main lines of the argument nor from the conclusions drawn.

V. ULTIMATE COMPOSITION OF THE IRON.

In the metal the greater part of the sulphur is combined with the manganese as a compound, which is much more stable than the accompanying sulphide of iron. The percentage of phosphide of manganese is negligible, as has been stated above, and the same may be said of the sulphide of manganese in the particular case under consideration, on account of the low percentage of sulphur. These two compounds need only be mentioned to show that they have not been forgotten. It will be assumed that two-thirds of the manganese is combined with the carbon and one-third with the silicon. This partition seems to be sufficiently justified by the difference of the heat of formation of the carbide and silicide.†

According to this, therefore, the metal is built up as follows:—

			Per Cent.
Carbide of manganese . . .	MnC_2	{ Mn. 1.00 } { C. 0.40 }	1.40
Silicide of manganese . . .	Mn_7Si_2	{ Mn. 0.50 } { Si. 0.14 }	0.64
Phosphide of manganese . . .	Mn_3P_2	...	traces
Sulphide of manganese . . .	MnS	...	traces
Carbide of iron . . .	Fe_3C	{ Fe. 43.40 } { C. 3.10 }	46.50
Silicide of iron . . .	FeSi	{ Fe. 1.72 } { Si. 0.86 }	2.58
Phosphide of iron . . .	Fe_3P	{ Fe. 7.58 } { P. 1.40 }	8.98
Sulphide of iron . . .	FeS	...	traces
Free iron . . .	Fe	...	39.90
Total . . .			100.00

* If these formulæ are probable, the combination of their elements does not correspond with the same chemical compounds. This follows from the before-mentioned investigations of Troost and Hautefeuille.

† Troost and Hautefeuille, *loc. cit.*

VI. HEAT OF FORMATION OF THE CONSTITUENTS OF THE METAL.

The calorific power of carbide of manganese, when the carbon is burnt to carbonic anhydride, is given by the thermal equation—

$$a. \begin{cases} \text{MnC}_2 + 5\text{O} = \text{MnO} + 2\text{CO}_2 \\ x \qquad \qquad \qquad 95 \quad 2 \times 97.6 = 290.2 - x \text{ calories,} \end{cases}$$

or 290.2 calories if x , the heat of formation of the carbide, be zero.

For the molecule-gramme of carbide of manganese, when the carbon is burnt to carbon monoxide, this becomes—

$$b. \begin{cases} \text{MnC}_2 + 3\text{O} = \text{MnO} + 2\text{CO} \\ x \qquad \qquad \qquad 95 \quad 2 \times 29.4 = 153.8 - x \text{ calories,} \end{cases}$$

or 153.8 calories when $x=0$.

For the phosphide of manganese—

$$c. \begin{cases} \text{Mn}_3\text{P}_2 + 8\text{O} = 3\text{MnO} + \text{P}_2\text{O}_5 \\ 3x \qquad \qquad \qquad 3 \times 95 \quad 365.4 = 650.4 - 3x, \end{cases}$$

or $650.4 \div 3 = 216.8$ calories for unit manganese when $x=0$.

In the same way are found—

	Calories.
Sulphide of manganese	164.2
Silicide of manganese	157.2
Phosphide of iron	129.9
Carbide of iron { C burnt to CO ₂	101.5
C burnt to CO	78.8
Sulphide of iron	138.2
Silicide of iron	288.2*

All these totals must be diminished by the heat of formation of the compounds, which, in the case of the constituents of the pig iron, are often incomplete or ill-defined combinations. According to Troost and Hautefeuille† these heats are positive for the first six, and zero or negative but negligible for the latter four.

With the experiments of Troost and Hautefeuille as a starting-point, the author opines that he has a sufficiently near approximation for his object if he assumes that the heat of formation of carbide of manganese is two-fifths, and that of the sulphide, phosphide, and silicide of manganese, and also that of the phosphide of iron, are one-third of the heats that are produced by the com-

* In all cases it has been assumed that the iron has been burnt to the ferrous state. Oxidation to magnetic oxide gives only a slight increase, amounting to 296.5 calories in place of 288.2 in the case of silicide of iron. The numbers given above are therefore sufficiently approximate.

† *Loc. cit.*

bustion of the elements if supposed to be in a free state. The admitted heats of combustion are therefore as follows:—

	Calories.
Carbide of manganese	116·0
Phosphide of manganese	72·3
Sulphide of manganese	54·8
Silicide of manganese	52·5
Phosphide of iron	43·3

By deducting these figures from those given for the heats of combustion of the same compounds, the resulting heat of combustion of the constituents of the iron may be obtained.

VII. HEAT OF COMBUSTION OF THE CONSTITUENTS OF IRON.

Constituent.	Heat of Formation per Gramme-atom of the Metal.	Heat of Combustion of the Free Elements per Gramme-atom of the Metal.	Heat of Combustion Resulting per Gramme-atom of the Metal.
Silicide of iron	negligible	288·2	288·2
Carbide of manganese (C burnt to CO ₂)	116·0	290·2	174·2
Phosphide of manganese	72·3	216·8	144·5
Sulphide of iron	negligible	138·2	138·2
Sulphide of manganese	54·8	164·2	109·4
Silicide of manganese	52·5	157·6	105·1
Carbide of iron (C burnt to CO ₂)	negligible	101·5	101·5
Phosphide of iron	43·3	129·9	86·6
Carbide of iron (C burnt to CO)	negligible	77·7	77·7
Carbide of manganese (C burnt to CO)	116·0	153·8	37·8

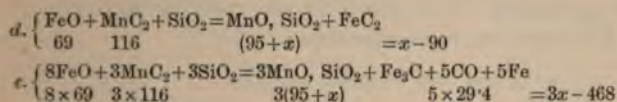
The figures in the last column are the differences between those given in the first and second columns. Those appertaining to the carbide, sulphide, and silicide of iron, of which the heat of formation has not been determined, but which is somewhat negative and at the same time negligible, are in reality somewhat too low, but the difference cannot influence the results.

VIII.—ORDER OF DISAPPEARANCE OF THE CONSTITUENTS DURING THE BLOW.

At this point it is necessary to refer to the well-known de-oxidising, carburising, and superheating effects that carbide of manganese * adds to the end of the operation, and to seek for its

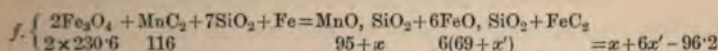
* The superheating of the bath, which has been found by Le Chatelier to be about 60° C., is especially noticeable when the additions are made in a molten state. Cold ferro-manganese requires for melting it an amount of heat equal or superior to that disengaged or arising from the reactions of the elements.

cause. Does the burnt iron contain oxygen as ferrous oxide or as magnetic oxide? Under the first supposition the reactions d and e may be expected:—



The equation d is satisfied when $x = 90$ calories, and the equation e when $x = 156$ calories. Therefore x , the heat of formation of silicate of manganese, must at least be equal to 90 calories for d to occur, and to 156 calories for e to take place. Up to the present time the heat of formation of silicate of manganese, starting with SiO_2 and manganese oxide MnO , has not been determined, but probably it does not reach 90 calories, judging by analogy with the carbonate MnO , CO_2 , of which the heat of formation is 19 calories.

By the second hypothesis, in which the oxygen is contained in the bath of burnt iron in the state of magnetic oxide, the reaction f will explain the phenomena of carburisation, deoxidation, and superheating:—



From this it would suffice for the heat of formation x of silicate of manganese to be + 40 calories, and that x' of silicate of iron to be + 20 calories, for this equation f to give a gain of heat of:—

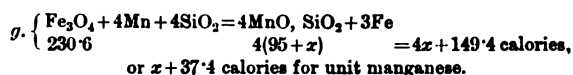
$$40 + 6 \times 20 - 96.2 = 63.8.$$

Therefore this reaction f gives the only means of explaining the operation of the phenomena which occur in the converter at the time of the final addition.

It is therefore certain that the burnt iron contains magnetic oxide and not the protoxide, and the rôle of the carbide of manganese, apart from its function as a recarburiser, is to reduce the magnetic to ferrous oxide, so that it may combine with silicon, and not to transform the protoxide of iron into protoxide of manganese. Any other oxide of manganese than the protoxide is not possible under the conditions obtaining in the converter, and the superoxidation which is an impediment to the trans-

ference of the ferrous oxide into the slag, is not to be feared as regards the protoxide of manganese formed.

It should be noted, when the additions contain free manganese, that the iron may be reduced to the metallic state, as is shown by the following thermal equation:—



Whatever the value of x may be, the resulting calorific effect is positive and noticeable.

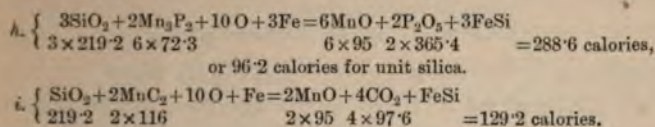
Probably this never occurs, even if the richest possible ferro-manganese is used, for in that case the carbon may cause the formation of Mn_3C , and, with the aid of the other metalloids, all the metal enters into a state of combination.

Now that this first point has been settled, it is important to notice that the carbon burnt at the beginning of the blow is disengaged as carbonic anhydride, and towards the end as carbon monoxide. The first gas, in fact, can only exist at the temperature reached by the bath during the slagging period. This is confirmed by analyses of the gas during different stages of the blow. It should also be remarked that the sulphur can only be absorbed by the slag as sulphur, sulphurous oxide being impossible under the heat conditions in the converter. These three points being cleared away, it is time to seek the explanation of the phenomena which occur during the blow.

All things being equal, and excluding extraneous circumstances, the order of attack of the constituents of the metal should be given by the list of resulting heats of combustion given above. This list begins with silicide of iron and finishes with that portion of carbide of manganese from which the carbon is burnt off as carbon monoxide. As a matter of fact, the actual order is different. It is well known that the successive reactions encroach one on the other to a certain extent, and this causes the defining lines between each step to be less distinct.

The silicide of iron at the head of the list is attacked first and gives silica and magnetic oxide. But the carbide and phosphide of manganese, when their percentages are sufficiently high, in the presence of iron or under the oxidising condition of a bath traversed by air under pressure, can reduce not only oxide of

iron but also silica, and this can be accounted for by the following thermal equations:—

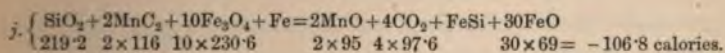


It must be noticed, however, that the production of carbon monoxide in place of carbonic anhydride in the latter equation *i* gives a calorific deficit.

The two reactions shown in *h* and *i* will occur in preference to that forming silicate of iron, as the latter gives off an amount of heat less than these totals 96.2 and 129.2. They explain the action on the manganese alone before the attack of the silicon during the first minutes of the blow with highly mangiferous irons, and also the analyses of Kupelwieser and Brunn, quoted in the above-mentioned paper by Hartley as relating to a Bessemer charge containing 3.46 per cent. of manganese and 1.96 of silicon. As these analyses deal with Bessemer metal containing only traces of phosphorus and sulphur, they can only be explained by the equation *i* due to carbide of manganese.

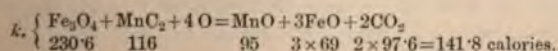
Carbide of iron in reacting on silica gives, as may easily be verified by referring to the thermal equation, a noticeable deficit of heat. It is also known that silica is not reduced by carbide of iron, whilst carbide of manganese is the best reducing agent for silicon in the blast-furnace, just as it is in the reverberatory and in the crucible in the manufacture of ferro-silicon.

It must be remarked that the reaction *i* can scarcely occur if the oxygen has to be supplied not by the blast but from the magnetic oxide. This is shown by the equation:—

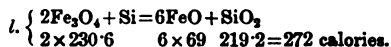


The equation *h* is only produced under these conditions.

The carbide of manganese therefore easily reduces the silica formed at the commencement, and it also easily reduces the magnetic oxide to ferrous oxide:—



The silicon burns at the expense of the magnetic oxide, and reduces it to ferrous oxide :—

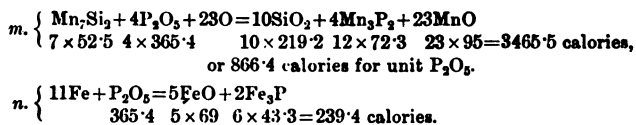


Comparison of the equations *i*, *k*, and *l* shows that the reaction *i* is only produced when there is an excess of carbide of manganese or an insufficiency of silicon. Comparison of the equations *i*, *k*, and *f* shows different results merely because the addition is made to a bath only containing combined oxygen.

This is one of the reasons why it is preferable not to turn the vessel up after an addition for a short afterblow, but to allow the reactions to take place in the turned-down converter or in the ladle.

If the manganese contents are sufficiently high, the first parts disappear at the beginning, and then the silica generated from the silicide of iron can combine with the ferrous oxide and with the manganese which has already oxidised and still continues to pursue that course.

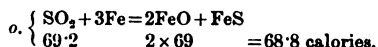
The phosphoric acid produced by the reaction *h* is reduced by the silicide of manganese and by the metallic iron :—



As the phosphate of iron only gives about 30 calories in its formation from the elements FeO and P_2O_5 , the reactions *m* and *n* preferably take place.

The remaining phosphide of manganese in its turn suffers decomposition. The metallic oxides produced combine with silica, and the phosphoric acid resumes its state of phosphide of iron as the equations *m* and *n* show.

The sulphide of iron does not burn after the phosphide of manganese because sulphurous acid cannot form, being always decomposed by the heat or reduced by the iron :—

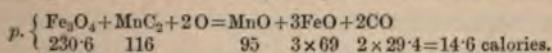


The sulphide of manganese burns subsequently; the metallic oxide combines with silica, and the sulphur constantly returns to the state of sulphide of iron.

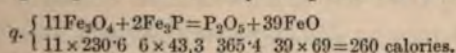
At this instant, part of the manganese which is combined with the carbon, and all the manganese as phosphide and sulphide have been burnt. The same has happened to the silicon combined with iron. These combustions have produced a considerable rise of temperature, on which account carbonic anhydride can no longer exist. Only part of the carbide of iron can therefore burn to give carbonic anhydride.

Silicide of manganese burns in its turn with the production of silicates.

The remaining carbide of iron, which forms the greater proportion of the total amount, and the carbide of manganese which has escaped up to the present then burn, giving off carbon monoxide—



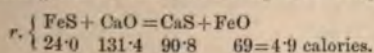
Finally, if the lining is basic and the blast is kept on for an afterblow, the slag becomes rich enough in oxide of iron and abundant enough for the phosphoric acid to pass into it as phosphate of iron at about +30 calories. The ferrous oxide required to saturate the phosphoric acid may be produced thus:—



In an acid converter, this result is never attained, and the phosphorus remains in the slag like the sulphur, which necessitates an even still more basic slag to absorb it.

In the basic converter the phosphate of iron formed in the slag is transformed immediately into phosphate of calcium on account of the lime introduced with the charge before blowing.

The transformation of sulphide of iron into sulphide of calcium gives a minimum gain of heat even by the very definite reaction—



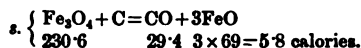
The principal part played by the lime as regards desulphurisation is to render the slag more basic, but as regards the phosphorus it has a double rôle, as it not only increases the basicity but it also absorbs the phosphoric acid to form the phosphate $3\text{CaO}, \text{P}_2\text{O}_5$.

IX. FINAL ADDITION.

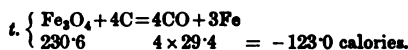
Manganiferous additions made after the blow act on the magnetic oxide, as has been shown above (*f*), and reduce it to

ferrous oxide and not to metallic iron. The loss of five units more in the basic than in the acid process is thus explained.

Free carbon as coke or briquettes can to a certain extent reduce the magnetic oxide—



But the reduction to iron is less probable—



By comparison of the thermal equations *f*, *s*, *t*, it will be seen that the result of the addition of free carbon is, on the whole, that it dissolves in the bath in order to bring up the metal to the required hardness.

X. FLUCTUATIONS OF TEMPERATURE DURING THE BLOW.

The weight of the air necessary to burn off the constituents of the iron may readily be calculated, and also the weight of the products of combustion and the heat carried off by them.

Calculating from the atomic weights, a kilogramme of silicide of manganese uses up 324 grammes of oxygen, and this corresponds to 1079 grammes of nitrogen. Assuming 1200°C . as the temperature of the flame at the mouth of the converter, the heat carried away by 1079 grammes of nitrogen, the only gas which remains from this combustion, is $1.079 \times 0.2438 \times 1200 = 315$ calories.

The other products of the combustion remain in the converter. The heat of combustion resulting from $1/7 \text{ Mn}_7\text{Si}_2 = 441 \div 7 = 63$ grammes of silicide of manganese, being 105.1 calories; one kilogramme of silicide produces 1666 calories, and leaves in the converter $1666 - 315 = 1351$ calories. The calorific efficiency is thus $1351 \div 1666 = 0.86$.

When the carbide of iron is burnt with the production of carbonic anhydride there is found in a similar manner—

Weight of oxygen required	268 grammes.
Weight of nitrogen	892 „
Heat carried off by the nitrogen	$0.892 \times 0.2438 \times 1200 = 256$ calories.
„ „ carbonic anhydride	$0.245 \times 0.245 \times 1200 = 71$ „
Total	327
Heat produced by combustion of 1 kilogramme of Fe_3C	1691
Useful heat	1364 calories.

A part of the carbon combined with the iron burns alone, and the heat given under these conditions must be investigated. The same is true of the silicon combined with the iron and of the manganese combined with the phosphorus. This presents no difficulty. In the case of carbide and silicide of iron, to obtain the heat of combustion per kilogramme of the silicon or carbon it is sufficient to take the figures given in thermo-chemical tables. For manganese phosphide use is made of the totals given above in the table of resulting heats of combustion, from which is deducted the heat due to the combustion of the phosphorus; the result is then referred to a quantity of 1000 grammes, from which again is deducted the heat carried off by the gaseous products of combustion. The following table has thus been calculated. In it no account is taken of the heat lost by solid matter ejected or volatilised from the converter, as they are difficult to value.

The heat radiated from the converter may be regarded as a constant which should be deducted from all the figures given in the table, leaving them therefore with the same numerical differences.

Heat in Calories Left in the Converter by the Combustion of One Kilogramme of each of the Constituents of the Iron.

Constituent.	Heat of Combustion.		Heat Carried off by the Gases per Kilogramme.	Heat Left in the Bath per Kilogramme.	Calorific Efficiency, per Cent.
	Per Gramme-atom of Free Metal or Metalloid.	Per Kilogramme of Constituent or of Free Metalloid.			
Silicon	219.2	7326	1096	6230	84
Silicide of iron	288.2	3430	450	2980	86
Silicide of manganese	105.1	1666	315	1351	81
Phosphide of manganese	144.5	1911	539	1372	71
Manganese of the phosphide metal only burnt	22.7	412	285	127	30
Sulphide of manganese	109.4	1257	178	1079	85
Carbide of manganese	174.2	2205	1009	1196	54
carbon burnt to anhydride					
Carbon in carbonic anhydride	97.6	8080	4592	3498	45
Carbide of iron	101.5	1691	327	1364	80
carbon burnt to anhydride					
Carbide of iron	77.7	1295	217	1078	83
carbon burnt to monoxide					
Carbon in monoxide	29.4	2450	2262	188	8
Carbide of manganese	37.8	478	638	-160	-33
carbon burnt to monoxide					
Phosphide of iron	86.6	1305	384	921	70
Free iron	69.0	1232	346	886	71

The order of attack of the constituents combined with the preceding table enables the variations of temperature of the bath to be followed. At the beginning the iron is heated by the combustion of the silicon (6230 calories), the silicide of iron (2980 calories), and the carbide of manganese (1196 calories). Then the loss due to the combustion of manganese combined with phosphorus (its 127 calories being insufficient to equal the loss by radiation, volatilisation, and ejected matter) is made up for by the combustion of manganese combined with sulphur (1079 calories), and of the silicide of manganese (1351 calories), which has not been already utilised in the reduction of phosphoric acid. The combustion of part of the carbon only (3498 calories), or carbide of iron (1364 calories), accentuates the elevation of temperature.

Soon the combustion of carbon into carbonic anhydride becomes no longer possible, and it is as carbon monoxide that the larger proportion of the carbon in the carbide of iron participates in the heating effect, either as carbon burning alone (188 calories) or with the iron (1078 calories). Then the bath cools in proportion as carbon monoxide is evolved. It becomes thicker, besides which the melting point becomes higher. The blast exercises its full effect on the free iron (886 calories), giving abundant oxide, which makes the metal pasty. The remainder of the carbide of manganese reduces part of the magnetic oxide, giving off carbon monoxide according to the equation p . The absence of foreign bodies such as silicon and carbon, and the small amount of manganese left, causes, in default of bodies which can reduce the magnetic to ferrous oxide, the oxide of iron in the first-named state to spread itself through the metal.

The great stability of carbide of manganese as revealed by its low resulting calorific power explains why it is not attacked except indirectly in the first instance, and why highly mangani-ferous iron can be treated without final additions. The Swedish direct process is an application of this fact that a considerable proportion of the carbide of manganese exists until the end of the blow, and plays the part of the final additions which have to be made in the ordinary acid and basic processes.

In the basic process, the phosphorus, which at the end of the blow is entirely in the form of phosphide of iron, adds two

sources of heat to the heat of combustion of Fe_3P (921 calories). These are due to the combination of the phosphoric acid first with the ferrous oxide resulting from the reduction of magnetic oxide under the influence of phosphide of iron according to equation *g*, and subsequently to the combination with lime. The first of these gives 484 calories and the second 2569 calories per kilogramme of free phosphorus, and this is the cause of the heating effect.

Lastly, the addition of manganese reduces the excess of magnetic oxide to the ferrous state when it combines with silica at the same time that oxide of manganese is generated, and this causes a last accession of heat provided that the matter added is in a fused state. The recarburiser at the same time lowers the melting point of the bath and increases its fluidity.

XI. COMPARISON OF THE ACID AND BASIC PROCESSES.

In comparing the two processes, it is seen that in the acid process the high percentage of silicon and the absence of lime causes the first stage to be very hot, much hotter than in the basic converter. On the other hand, as phosphorus is practically absent, and furthermore as it is not oxidised at all, the heating due to the elimination of phosphorus at the end of the blow is absent. This heating in the basic process decreases to zero when there is an abundance of slag to take up a considerable part of the heat.

A comparatively cold charge is to be feared less in the acid than in the basic converter, because hot iron from a cupola surcharged with coke insures a good blow.

Lastly, the two consecutive heatings in the bath in the dephosphorising process show that it lends itself more advantageously than the acid method to the use of free carbon as a substitute for part of the ordinary recarburiser. As a matter of fact, the temperature is so high that powdered coke or carbon briquettes can easily reduce part of the magnetic oxide to the ferrous state, and thus diminish the quantity of manganese which would otherwise have to be added.

XII. COMPARISON OF THE BESSEMER PROCESS WITH REFINING.

The old process of refining pig iron is comparable with the first stage of the blow in an acid-lined converter. In both processes there is the absence of basic slag and strongly oxidising atmosphere, and also the silicon is nearly the only substance eliminated. The irons formerly used in the finery contained but little manganese. None of the analyses in the author's knowledge bear upon this assertion, but it appears to be the most probable. Manganese, if it did exist to any marked extent, would have been partly removed, and the analyses agree with this.

XIII. COMPARISON OF THE BESSEMER PROCESS WITH PUDDLING AND WITH THE PROCESSES OF BELL AND BENDER-KRUPP.

Two essential differences characterise the puddling and the Bell and Bender processes as compared with the Bessemer process. The first is that the oxygen is introduced almost entirely by the oxides of iron Fe_2O_3 and Fe_3O_4 contained in the slag or in the additions. The second is that the slag is abundant and basic from the start. It results from the first of these that the reaction *i* cannot take place and, since the reaction *j* gives a calorific deficit, the carbide of manganese cannot reduce the silica formed in the first instance. The silicon therefore ought always to disappear first, and the manganese follows. From the second point it results that the phosphorus may be eliminated before the carbon. Phosphide of manganese as it burns gives 144.5 calories per gramme-atom of manganese, phosphide of iron 86.6 calories, and carbide of iron only 77.7 calories when the carbon is burnt to monoxide. The difference is much more in favour of the phosphorus in that the phosphoric acid gives additional heat by its combination with oxide of iron. Altogether the dephosphorisation is not so complete as in the Thomas and Gilchrist process. The temperature is not so high on account of the fact that less heat is obtained from the formation of phosphate of iron as compared with that from phosphate of calcium. If the sulphur partly disappears in the puddling furnace, it does so before the free elimination of the carbon, for then the slag covers the metal and the reactions take place not in the body of the metal but at the clearly marked surface dividing

the two layers. The sulphides of iron and manganese, therefore, have time to dissolve partially in the basic silicate.

XIV. TABLE SHOWING THE HEATS OF FORMATION
USED IN THIS PAPER.

Name.	Components.	Formula.	Molecular Weight.	Heat Disengaged.
				Calories.
Sulphurous anhydride . . .	S + O ₂	SO ₂	64	69·2
Phosphoric anhydride . . .	P ₂ + O ₅	P ₂ O ₅	142	365·4
Silica	Si + O ₂	SiO ₂	60	219·2
Carbon monoxide	C + O	CO	28	29·4
Carbonic anhydride	C + O ₂	CO ₂	44	97·6
Manganous oxide	Mn + O	MnO	71	95·0
Ferrous oxide	Fe + O	FeO	72	69·0
Magnetic oxide	Fe ₃ + O ₄	Fe ₃ O ₄	232	230·6
Ferrous sulphide	Fe + S	FeS	88	24·0
Calcium sulphide	Ca + S	CaS	72	90·8
Phosphate of calcium	3CaO + P ₂ O ₅	3CaO, P ₂ O ₅	310	159·6
Phosphate of iron	FeO + P ₂ O ₅	FeO, P ₂ O ₅	214	30·0

With the exception of the last number, which is adopted by Mr. Pourcel in his previously quoted work, all of them are taken from *L'Annuaire du Bureau des Longitudes* for 1897 except the figure 179·6, which is there given as the heat of formation of silica. This is a printer's error which has appeared since 1895. It is here replaced by the number 219·2 given in the previous volumes.

DISCUSSION.

Mr. G. J. SNELUS, Vice-President, thought all the members would admit that the paper was much too abstruse to be dealt with, as it had been, in abstract; and even if it had been read in full, he feared the members would carry away very little of its contents. He had himself read the paper somewhat carefully, but confessed that he was not able to follow all the arguments. He was a little surprised that the author had not referred to the first paper "On the Thermo-Chemistry of the Bessemer Process," written by Professor Åkerman, who was the first chemist to show how the reactions in the process produced heat. He remembered reading the paper a great many years ago. At that time it was not known that the oxidation of carbon during the process gave rise to carbonic oxide. It was always supposed that the action of the air upon the carbon in the metal gave rise entirely to carbonic acid, that all the carbon was burnt to carbonic acid; and the original calculations were based on that supposition.

While he was at Dowlais he happened to be anxious to ascertain what was really the reaction which took place during the blow, and one of his first experiments there nearly thirty years ago was to collect the gas from the Bessemer converter and analyse it, and to his great surprise he discovered that the carbon was not entirely burnt to carbonic acid. During the first half of the blow they had carbonic acid, but then the temperature rose to such an intense point that carbonic acid could not exist, and carbonic oxide was the product that was given off. He believed that those tests were the first ever made on the composition of the gases from the Bessemer converter. Having ascertained what was the composition of the gases coming off, he himself made the thermal calculation and published it in an article in "Muspratt's Chemistry as Applied to the Arts and Manufactures," published by Mackenzie. That was nearly twenty years ago. That article, he believed, explained all the reactions that took place, and it was assumed that those reactions took place in a much more simple manner than the author of the present paper

thought was the case. He could not help thinking that he had elaborated the reactions far too much. For example, when he spoke of the way in which phosphorus went out, he assumed that the phosphorus was oxidised and then combined with oxide of iron, that a further decomposition took place, and that then it combined with the lime. He really could not see why the phosphorus, being oxidised to phosphoric acid, could not be combined with the lime direct. He did not see what they wanted with the intermediary, and he saw no proof that it took place. It was an assumption, perhaps, based upon chemical theory, but he thought that theory was quite as strong in favour of a direct combination of the phosphorus with the lime.

Some of the members might recollect that for a long time after the basic process was brought out, their French friend, Mr. Pourcel, maintained that the phosphorus remained combined with the oxide of iron, that it was the oxide of iron really which took up the phosphorus and held it. That theory had been entirely exploded, and the suggestion that he (Mr. Snelus) threw out at the time of the reading of those early papers, that the calcium acted as the great agent in the process, tribasic lime phosphate being found, had been thoroughly established. The author of the paper had come to the same final conclusion, but he put a step in between, and assumed that the phosphate of iron was first formed, and then that the phosphate was decomposed. He did not quite see the necessity of that intermediate reaction. He thought that the phosphorus, being oxidised, was bound to be oxidised to phosphoric acid. Being oxidised to phosphoric acid, it seized upon the strongest base. It had the strongest affinity for lime, and combined with it direct. He did not think that the intermediate step took place. He might be wrong, but he should like to see further proof than a mere theorising on the subject before giving up his own ideas. No doubt the paper was a very elaborate and useful one, and he was sure that many of the members would carefully study it. They were very much obliged to the author for taking so much pains in trying to unravel what was a very difficult chemical problem.

Mr. SANITER said there was one point raised in the paper upon which he should like to say a few words,—he referred
1897.—ii.

especially to the allotment by the author of the metalloids to the manganese. It was well known that at the temperature of molten pig iron the sulphur did combine with the manganese, and no doubt the other metalloids might be considerably alloyed with the manganese at that temperature. But when they came to the temperature of the solidifying of mild steel, they found the curious fact, that although the sulphide of iron, the carbide of iron, and the phosphide of iron segregated to the centre of the ingot, the manganese did not increase; this apparently indicating that at that temperature the sulphur, the phosphorus, and the carbon were not combined in any preferential manner with the manganese in the steel. It seemed to him, therefore, that the heat reactions mentioned in the paper would be to a certain extent modified by taking that view of the decomposition of the various carbides, phosphides, and sulphides during the rise of temperature of the blow.

The PRESIDENT proposed a hearty vote of thanks to Professor Ponthière for his paper, and expressed a hope that when the members had had time to study it they would communicate their views to the Secretary in writing on the subject. He thought it was a paper that should not be allowed to drop, containing, as it did, a large amount of most interesting information.

The motion was carried by acclamation.

The following paper was then read:—

CARBON AND IRON.

BY ERNEST HENRY SANITER (WIGAN).

So much valuable work has been done on this subject, in the last few years, and so much has been added to existing knowledge, that it might seem to the casual observer almost superfluous to endeavour to throw new light on the problems connected with the relation of carbon to iron. But those who have followed closely the progress which has been made recognise that there is yet much to be learnt.

It has occurred to me that there were several directions, old and new, by the investigation of which additional information might be gained on this important subject.

The directions which suggested themselves to me were as follows:—

- (1) The thermal treatment of Fe_3C .
- (2) The saturation-point of iron with carbon by fusion in contact with excess of carbon.
- (3) The saturation-point of iron with carbon by heating without fusion in contact with excess of carbon.
- (4) The etching of pure carbon-iron alloys at a red heat, in order to ascertain their structure by means of the microscope at that temperature.

In the following pages are given the results of these investigations, which it is hoped may, in some small degree, assist in bringing to a conclusion some of the vexed points in the relation of carbon to iron.

TRI-BASIC CARBIDE OF IRON (Fe_3C).*Preliminary Remarks.*

About 20 grammes of Fe_3C were prepared from a "cement bar," made from Wigan "Pure Quality" steel, containing 1.0 per cent. of carbon.

The carbide was prepared by the modification of Binks and Weyl's method described by Arnold and Read.*

The yield of Fe_3C obtained was 14.0 per cent. as against a theoretically possible yield of 14.5 per cent.

It was observed, on boiling a portion of the Fe_3C thus prepared with nitric acid of 1.20 specific gravity, that the coarser portion, *i.e.* that obtained from the cementite veins, was comparatively insoluble as compared with the fine flakes obtained from the pearly constituent.

An experiment was therefore made to ascertain if this peculiarity might be utilised to estimate quantitatively the cementite, and further to ascertain if the cementite thus separated had the same composition as the Fe_3C obtained from the pearly constituent.

A weighed portion of the Fe_3C was boiled for twenty minutes in 1.20 specific gravity nitric acid. The insoluble portion was then washed by decantation, dried with alcohol and ether, and weighed.

Assuming that the carbon in the original bar, exceeding 0.89 per cent., would exist as veins of cementite, the Fe_3C prepared from the bar (1.0 per cent. carbon) should contain 11.0 per cent. of cementite; the amount actually found was 9.8 per cent., which had the following composition:—

	Per Cent.
Carbon	7.23
Iron	89.90
Not accounted for	2.87
	<hr/> 100.00

The cementite separated was of a bronze colour and was evidently partially decomposed, as was shown by the deficiency in the analysis. The deficiency is not, however, much greater than that shown by the first batch of Fe_3C , the analysis of which (carbon, 6.92) is given later on. This experiment is therefore favourable to the supposition that the Fe_3C from the cementite and pearlite have the same composition.

In the following table are given the results of the thermal treatment of Fe_3C under varying conditions:—

* *Journal of the Chemical Society*, 1894, p. 790.

Thermal Treatment of Tri-Basic Carbide of Iron, Fe₃C.

	Wigan "Pure" Cement Bar.	Fe ₃ C Normal.	¹ Fe ₃ C heated to about 1000° C. in and chilled in cold water.		² Fe ₃ C heated to about 800° C. in Atmosphere of Nitrogen.†		³ Fe ₃ C heated to about 1000° C. in Atmosphere of Nitrogen.†		⁴ Fe ₃ C fused in Magnesia in Atmosphere of CO.	
		1st Series.	2nd Series.		1st Series.	2nd Series.	1st Series.	2nd Series.	1st Series.	2nd Series.
Silicon	Trace.	...	...	...	...	...	...	...	...	...
Silica	Nil.	0.09	...	...	...	...	...	...	...	...
Phosphorus	0.008	0.004	...	...	...	...	...	...	...	...
Sulphur	0.014	...	...	...	...	...	...	...	0.05	...
Manganese	0.16	0.15	...	...	...	...	...	...	...	...
Iron . . . . .	...	91.10	91.80	92.6	93.4	93.0	92.7	95.40	...	...
Loss on heating in nitrogen . . . . .	...	1.48	1.35	...	...	...	...	...	...	...
Not accounted for . . . . .	...	1.05	0.44	1.05	0.23	0.63	0.88	...	...	...
Total carbon	1.0	6.92	6.68	6.13	6.12	6.13	6.20	4.27	...	...
Graphitic carbon	Trace.	0.19	0.22	0.56	0.40	2.50	2.41	3.05	...	...
Combined carbon (by difference)	1.0	*5.94	*5.95	5.57	5.72	3.63	3.79	1.22	...	...
Combined carbon (by colour) . . . . .	...	...	...	...	...	...	3.58	...	...	...
Molecular ratio of total carbon to iron . . . . .	...	1:2.82	1:2.94	1:3.24	1:3.27	1:3.25	1:3.20	1:4.80	...	...
Molecular ratio of combined car- bon to iron . . . . .	...	1:3.28	1:3.31	1:3.55	1:3.49	1:5.49	1:5.25	1:10.61	...	...

* Allowance made for carbon hydrate.

† The nitrogen (and argon) was prepared by passing air over heated copper and then through pyrogallate of soda solution. It was also thoroughly dried before coming in contact with the Fe₃C.

The heating in No. 1 experiment occupied five minutes, the Fe_3C being enclosed in a copper tube. In Nos. 2, 3, and 4 the heating occupied half-an-hour. Nos. 2, 3, and 4 were allowed to cool down slowly *in situ*.

The second preparation of Fe_3C shows 0.44 per cent. unaccounted for, and a loss on ignition in nitrogen of 1.35 per cent., and contains practically the theoretical quantity of carbon. After ignition, all the experiments show more or less of the material unaccounted for. This probably vitiates to some extent the ratios of carbon to iron, as it seems probable that this "unaccounted-for" portion may be oxygen which has combined with the iron during the preparation of the Fe_3C .

It is interesting to note that the impurities found in the cement bar are also in the Fe_3C prepared from it, in practically the same proportions, thus showing that these impurities are disseminated equally throughout the Fe_3C and the ferrite.

Nothing peculiar was observable to the eye during the heating of the Fe_3C in nitrogen; but after allowing to cool, and removing the boat, it was found that the Fe_3C had become matted together like felt. The gases evolved during heating had a smell of hydrocarbon, which is confirmed by the loss of carbon in all cases when the carbide was heated.

It is noteworthy that in Experiments 1 and 2 very little graphitic carbon has been liberated, while in 3 and 4 increasing quantities of graphite are formed; that is to say:—

		Graphite, per Cent.
When heated to about 800° C. and slowly cooled	little graphite } is formed }	0.40
When heated to about 1000° C. and chilled	little graphite } is formed }	0.56
When heated to about 1000° C. and cooled slowly	much graphite } is formed }	2.45
When fused at about 1400° C. and cooled slowly	most graphite } is formed }	3.05

After these experiments were completed, I discovered that a somewhat similar investigation had been carried out on Fe_3C by Mylius, Foerster, and Schoene.* These investigators state that heating Fe_3C to a red heat does not alter it, which differs from my

* *Zeitschrift Anorg. Chem.*, 1896, vol. xiii. pp. 38-58.

experiments. They also melted the carbide, and obtained a button containing 4.36 per cent. carbon, as against 4.27 per cent. in my experiment. They, however, state that the button was white, with a radial structure like spiegeleisen, while my button was grey, and contained 3.05 per cent. graphite. Possibly these differences may be due to the fact that the carbide used by Mylius contained 1.1 per cent. manganese, while mine only contained .15 per cent.

SATURATION-POINT OF IRON WITH CARBON BY FUSION IN
CONTACT WITH EXCESS OF CARBON.

This saturation-point has been the subject of various investigations in the past, amongst which may be mentioned that of Karsten, who says that iron can combine with 5.95 per cent. of carbon. Percy, however, doubts this, and I agree with him; Riley,* who found 4.0 per cent. of carbon as the saturation-point; and, finally, Hochstätter,† who found 4.63 per cent. of graphitic carbon, with 95.13 per cent. of iron, leaving 0.24 per cent. unaccounted for, a considerable part of which was no doubt silicon, as the peroxide of iron and carbon used were admittedly not quite pure.

In view of these varying and doubtful results, it seemed desirable to redetermine this saturation-point. My endeavour was to produce a carbide entirely free from silicon. In this, even when using the greatest precautions, I was not entirely successful, as the following table will show:—

* *Journal of the Iron and Steel Institute*, 1877, No. I. p. 161. Mr. E. Riley having questioned the accuracy of this quotation, I find on reference that Mr. Riley stated that after two days' heating he found 4.75 per cent. of carbon as the saturation-point. I regret the mistake, which has arisen through a misquotation in Howe's "Metallurgy of Steel," p. 5, from which the statement was taken.

† Percy, "Iron and Steel," pp. 114, 115.

CARBON AND IRON.

Stead's Pure Wire Used.		No. 2 Button. Started with Wire.	No. 3 Button. Started with Wire.	No. 4 Button. No. 3 Remelted.	No. 5 Button. Fused Fe ₃ C.	No. 6 Button. Started with Wire.	No. 7 Button. Grey Portion of No. 6 Remelted.	No. 8 Button. No. 7 Remelted.
Total time molten at about 1400° C.		2½	3½	6½	½	3	4½	5½
No. of times melted		1	1	2	1	1	2	3
Fracture		{ Grey, with white centre crystalline }		{ Grey, with few patches of white }		{ Grey white centre white centre }		All grey
Manganese, copper		Trace	...	...	...	...	...	...
Phosphorus		0.014	...	...	...	...	...	...
Sulphur		0.011	0.013	...	0.05	Nil.	Nil.	0.005
Silicon		Trace	0.19	0.07	...	0.024	0.04	0.07
Iron (by difference)		99.975	96.31	95.94	95.43	95.93	95.13	95.19
Total carbon		Trace	3.47	3.97	4.27	4.03	4.81	4.73
Graphitic carbon . . . . .		...	...	...	3.05	3.00	3.84	4.03
Combined carbon (by difference)		...	2.00	...	1.22	1.03	0.97	0.70
Molecular ratio of total carbon to iron . . . . .		...	1:5.93	1:5.19	1:4.8	1:5.11	1:4.24	1:4.3
Molecular ratio of combined carbon to iron . . . . .		...	1:10.4	...	1:16.61	1:20.14	1:21.21	1:29.56

All the buttons were allowed to cool slowly in the crucibles.

Crucible Linings—No. 2,—10 per cent. lime; 2 per cent. calcium chloride; 88 per cent. pure lamp-black. No. 5, Magnesia (contaminated with sulphur). Nos. 3, 4, 6, 7, 8,—20 per cent. lime; 4 per cent. calcium chloride; 76 per cent. lamp-black.

It is observable that even a few hundredths per cent. of silicon has a marked effect in increasing the formation of graphitic carbon in saturated carbon-iron compounds, and it yet remains to be proved whether iron saturated with carbon, and quite free from silicon, could liberate graphite. It may, however, be taken for granted that 0.04 per cent. silicon (Exp. 7) will not reduce the saturation-point of iron for carbon by much, and therefore that 4.81 per cent. is not far off the truth.

Comparing Experiments 5 and 7 we notice a curious fact:—

Starting with	In contact with	Gives in Metal
Carbonless iron	Carbon,	4.81 per cent. carbon.
Fe_3C (carbon 6.13)	Magnesia,	4.27 " "

In both cases the fusion was in an atmosphere of carbonic oxide. Is the whole of the carbon loss from Fe_3C simply expelled, or is some removed by oxidation by magnesia, as shown to take place under similar conditions with lime by Mr. Stead?

Several of the buttons, including No. 7 (4.81 per cent. carbon), were white in the centre with grey outside. The white portion did not shade off gradually into mottled and then grey, the division being sharp, so that the grey portion could be cut and filed away from the white, as was done in the case of No. 6 button, the separate portions being tested for carbon as follows:—

	White.	Grey.
Total carbon	3.83	4.06
Graphitic carbon	Nil.	3.50

The proportion was about 1 of white to 6 of grey.

The microscopic examination of No. 7 button showed the white portion to consist of pearlite and cementite, while the grey consisted of pearlite, graphite, and ferrite.

THE SATURATION-POINT OF IRON WITH CARBON BY HEATING WITHOUT FUSION IN CONTACT WITH EXCESS OF CARBON.

This experiment was made to ascertain how much carbon could be taken up by pure iron without melting it, and to ascertain if the amount taken up was in molecular proportion to the iron.

Very pure iron wire, 0·04-inch in diameter, was heated to about 900° C. for varying periods in a porcelain tube full of charcoal, and at successive stages the tube was allowed to cool, and a portion of the wire removed for analysis.

The following table shows the results :—

	Pure Iron* Wire.	Same after Seven Hours' Heating.	Same after Fourteen Hours' Heating.	Same after Twenty-one Hours' Heating.
Manganese, silicon, } copper }	Trace.	...	...	...
Total carbon	Trace.	1·64	2·79	2·95
Graphitic carbon . . .	...	...	...	0·53
Combined carbon (by difference) . . . }	...	...	...	2·42
Sulphur	0·011	...	...	...
Phosphorus	0·014	...	...	...
Iron (by difference) .	99·975	98·33	97·18	97·03
Molecular ratio of total carbon to iron }	...	1:12·8	1:7·46	1:7·07
Molecular ratio of combined carbon to iron . . . . }	...	...	...	1:8·55

In every case the wire was allowed to cool down in the tube.

It will be seen from the above figures the rate at which the carbon was absorbed by the iron, viz. :—

First seven hours	1·64 per cent. carbon absorbed.
Second seven hours	1·15 " " "
Third seven hours	0·16 " " "

As only 0·16 per cent. of carbon was absorbed in the last seven hours, it was concluded that the saturation-point had been reached at 2·95 per cent., of which amount 0·53 per cent. was in the graphitic state.

Microscopic Examination.—Wire of the first and second period consisted of pearlite with bands of cementite extending in all directions from side to side. The wire after the third heating, while consisting of pearlite, cementite, and graphite (which last I was unable to detect with the microscope), showed a segregation of the cementite toward the centre, none of the bands extending to the outside, thus showing a tendency to form a white nucleus

* This wire was kindly sent to me by Mr. Stead. The analysis given is his.

similar to that found in the buttons produced by fusion described under another head. The outside of the wire was coated with graphite, which was carefully removed before the analyses were made.

THE ETCHING OF PURE CARBON-IRON ALLOYS AT A RED HEAT,
IN ORDER TO ASCERTAIN THEIR STRUCTURE AT THAT TEM-
PERATURE, BY MEANS OF THE MICROSCOPE.

In considering this, the most interesting part of my subject, it occurred to me, that if steel could be etched at a bright-red heat so as to show the distribution of the carbon, it would throw valuable light on the controversy which has now raged for some years on the hardening of steel.

What was required was a compound readily fusible at a red heat, which would have a selective action in attacking iron and carbide of iron at that temperature. In considering what might be suitable I was naturally led to think of calcium chloride.

On trying this reagent I was able to observe, with the naked eye, that the cementite veins were eaten away much more readily than the mass of the metal.

Photo-micrograph No. 1 shows this very clearly. The dark bands indicate where the cementite (Fe_3C) veins have been eaten away.

Method of Etching.—The piece of steel is polished in the usual manner. Calcium chloride is fused in a platinum crucible over a blast blow-pipe. When the fused chloride has reached a bright-red heat the piece of steel is dropped in and immersed by shaking.

The crucible is kept at a bright red till the piece of steel attains that temperature; after a further fifteen seconds' heating, the crucible is rapidly cooled by dipping the bottom into cold water. The steel is then rapidly dissolved out with water and dried in alcohol.

Having thus obtained a reagent which would act selectively on steel at a bright-red heat, the next step was to ascertain what the quantitative action of the calcium chloride was.

For this purpose weighed portions of very fine drillings of 1.8 carbon and 1.0 carbon cement bar were heated for varying times in fused calcium chloride at a bright-red heat, the loss of weight

and the carbon content of the remainder being ascertained. The following are the results:—

Time in Fused Calcium Chloride.	Carbon in Drillings before Treatment.	Carbon in Drillings after Treatment.	Carbon Dissolved.	Iron Dissolved.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1 minute . . .	1·8	·52	1·33	9·72
2 minutes . . .	1·8	·11	1·71	13·31
3 minutes . . .	1·8	·09	1·72	19·00
$\frac{1}{2}$ minute . . .	1·0	·90	·16	6·29
1 minute . . .	1·0	·68	·37	6·58
$1\frac{1}{2}$ minute . . .	1·0	·51	·53	7·42

It would appear from these experiments that

(1) The cementite is dissolved bodily until a certain amount of oxide of iron is floating in the fused chloride. This is confirmed by Fig. No. 1 (Plate V.).

(2) The carbon then begins to be removed without further solution of iron. This is probably caused by the floating oxide of iron in a manner analogous to the removal of carbon by cementing with oxide of iron.

(3) As soon as the carbon is nearly all removed, the iron is again rapidly dissolved.

As will be remembered from the description of the method of etching, the process was stopped before the end of the first period, *i.e.* while both carbon and iron were being dissolved.

A series of pure steels with ascending quantities of carbon were now etched by this method. On examining them, magnified to 250 diameters, a most interesting structure was revealed, a structure which is closely identified with the percentage of carbon present.

Photo-micrographs 2 to 6 of steels containing from 1·8 to 0·10 per cent. carbon show fairly well the structure as revealed by the microscope. It should, however, be mentioned with reference to Nos. II. and III. that parts of the specimens free from cementite, or to speak more correctly, from where the cementite had been, were purposely selected, so that they may be considered as steels containing about 0·9 per cent. carbon.

It will be observed that Nos. II. and III. exhibit a very characteristic structure, which appears to consist of acicular crystals, which show a marked tendency to form triangles.

No. IV., 0.6 per cent. carbon, shows this acicular structure strongly, while in No. V., 0.43 per cent. carbon, it is only faintly marked, and in No. VI., 0.1 per cent. carbon, it is entirely absent. The dark network on each of the plates is the ordinary granular junctions, which are well brought out by this method.

These acicular crystals are, in my opinion, an indication of a definite carbide of iron existing in steel at a bright-red heat; and if, in accord with present theory on the subject, the carbon is retained to a large extent by chilling, in the form in which it exists in steel at a bright-red heat, it follows, as a natural corollary, that these acicular crystals are the hardening carbide in steel.

As it might be argued that the dark lines on Nos. II., III., and IV. are lines of carbide or carbon of a different colour, as in nitric-acid etching, I may point out that they are only shadows caused by the facets of the crystals, the whole surface of the metal being bright and free from stain. Osmond, who, in examining that microscopic appearance of varying composition, known as Martensite, and lately alluded to in one of its forms by Sauveur as "diluted Martensite," has discovered triangular shapes which he describes as "triangular crystallites of iron," presumably allotropic iron. These triangles appear to be the connecting feature between Martensite and the acicular structure at a red heat, and are, no doubt, the triangles formed by the acicular crystals. This naturally leads us to consider how the allotropic theory stands towards this method of investigation.

This theory assumes the formation of a hard allotropic modification of iron at a bright-red heat, which is retained in that form by chilling when there is sufficient carbon present, it being assumed that the carbon acts as a brake* to retain the iron in its hard or β -condition. Of course this hard condition of iron is also assumed to exist in carbonless iron at a bright-red heat.

Before proceeding further, it seems desirable to emphasise the fact that the structure exhibited in the plates was deeply etched upon the steel at a bright-red heat; this and the subsequent

* As already pointed out by me (Discussion on Hogg's Paper, *Journal of the Iron and Steel Institute*, No. II., 1896), this brake action can only act, if it does act, on the pearly constituent, as cementite does not harden by chilling, and therefore carbon in excess of about 0.89 per cent. cannot act as a brake.

rapid chilling prevents doubt as to the structure being other than that at a bright-red heat.

Now, if the acicular structure obtained by etching with fused calcium chloride were an indication of the "adamantine allotropic modification of iron," it would be equally evident with 0·1 per cent. carbon as with 1·8 per cent. carbon, but it is entirely absent.

We therefore come to the point that at a bright-red heat iron containing 1·0 per cent. carbon has a totally different structure from iron containing 0·1 per cent. carbon, and that this difference of structure is due to the carbon *per se*.

Likewise in chilled steel we have a great difference in physical characteristics between 1·0 and 0·10 per cent. carbon, which cannot exist without the difference in carbon.

This method of investigation, while it gives no indication of an allotropic modification of iron, gives strong evidence that 0·6 per cent. carbon or upwards causes, at a bright-red heat, a radical change in the structure of iron, which must be considered as evidence in favour of the hardening of steel being due to an attenuated carbide of iron of great hardness.

Before leaving this part of my subject I should mention that, etching some steel containing small quantities of aluminium by this method, I was unable to obtain the acicular structure, which induces me to believe that aluminium, even in small quantities, may have a very marked effect on the state of the carbon in chilled steels.

Etching by fused calcium chloride might yield further information if steels were etched at carefully-regulated temperatures corresponding with the recalescence points, as I have myself obtained distinct indications of pearlite by etching at a dull red.

The following table shows the molecular ratio of carbon to iron found in the various stages of the foregoing experiments, arranged in descending order of the carbon :—

Description of Experiment.	Total Carbon.	Combined Carbon.	Ratio of Total Carbon to Iron.	Ratio of Combined Carbon to Iron.
	Per Cent.	Per Cent.		
Fe_3C normal	6.92	...	<i>1:2.82</i>	...
" " " "	6.68	...	<i>1:2.94</i>	...
" " heated to 1000°C .	6.20	...	<i>1:3.20</i>	...
" " chilled from 1000°C .	6.13	...	<i>1:3.24</i>	...
" " heated to 1000°C .	6.13	...	<i>1:3.25</i>	...
" " " " 800°C .	6.12	...	<i>1:3.27</i>	...
Fe_3C normal	...	5.94	...	1:3.28
" " " "	...	5.95	...	1:3.31
" " heated to 800°C}.	...	5.72	...	1:3.49
" " chilled from 1000°C}.	...	5.57	...	1:3.55
Wire fused for $4\frac{1}{2}$ hours	4.81	...	<i>1:4.24</i>	...
" " " " $5\frac{1}{2}$ hours	4.73	...	<i>1:4.30</i>	...
Fe_3C " " $\frac{1}{2}$ an hour	4.27	...	<i>1:4.8</i>	...
Wire " " 3 hours	4.03	...	<i>1:5.11</i>	...
" " " " $6\frac{1}{2}$ hours	3.97	...	<i>1:5.19</i>	...
Fe_3C heated to 1000°C}.	...	3.79	...	<i>1:5.25</i>
" " " "	...	3.63	...	1:5.49
Wire fused for $2\frac{1}{2}$ hours	3.47	...	<i>1:5.93</i>	...
Wire cemented for 21 hours	2.95	...	<i>1:7.07</i>	...
" " " " 14 hours	2.79	...	<i>1:7.46</i>	...
" " " " 21 hours	...	2.42	...	1:8.55
Wire fused for $3\frac{1}{2}$ hours	2.0	...	<i>1:10.4</i>	...
" " " "	...	2.0	...	<i>1:10.4</i>
Wire cemented for 7 hours	1.64	...	<i>1:12.8</i>	...
Fe_3C fused for $\frac{1}{2}$ an hour	...	1.22	...	<i>1:16.6</i>
Wire fused for 3 hours	...	1.03	...	<i>1:20.14</i>
" " " " $4\frac{1}{2}$ hours	...	0.97	...	<i>1:21.21</i>
" " " " $5\frac{1}{2}$ hours	...	0.70	...	<i>1:29.5</i>

In considering these ratios with reference to the formation of definite carbides of iron, I am going on the assumption, an assumption which I think is well justified by observed facts, that molten iron contains no graphite, and that as it solidifies the graphitic carbon is first liberated, and that the remaining carbon, known as combined, then exists either in solution in the iron, or combined with it as a definite carbide other than Fe_3C , which latter is formed as the slowly-cooling mass falls still further in temperature.

The ratios which seem the more important are given in italics.

It will be noticed that the ratios for cementite are not quite 1:3, but if we assume that the hydrate of carbon present should be combined with the iron partially oxidised (as indicated by the unaccounted-for portion), and deduct the graphitic carbon from

the total, we get the following corrected ratios of 1:2.90 and 1:3.04, average 1:2.97, which confirms the results of many previous observers.

We now come to the ratio 1:5, *i.e.* 4.1 per cent. carbon. E. Riley, as already mentioned, found 4.0 per cent. carbon to be the saturation point for iron by fusion. In addition to this, in two of my experiments by fusion with carbonless iron I have met with a halt in the absorption of carbon about this point, *i.e.* at 3.97 per cent. and 4.03 per cent., while Fe_3C fused expelled its carbon down to 4.27 per cent., and heating Fe_3C to 1000°C . in nitrogen reduced the amount of combined carbon to 3.79. The average of these results, including Riley's, give a ratio of 1:5.1, which, considering the surrounding circumstances, seems worthy of attention.

The next ratio to be considered is that of 1:7.0. The saturation of iron by cementation gives a ratio of 1:7.07. The nearness of the ratio to whole numbers is remarkable, but in the absence of confirmation by other methods it cannot be regarded, at present, as other than a coincidence.

Ratio of 1:10.4, 2.0 per cent. carbon.

In view of the hypothetical Fe_{10}C suggested by Arnold as being the formula for a carbide existing in low carbon steels outside of the pearlite, it may be interesting to mention the physical character of a metal of this composition made by fusion. It is of such a highly-crystalline nature, that, on breaking it, detached crystals drop out.

Ratio, 1:20 and 1:30.

In view of Arnold's hypothetical Fe_{24}C , it seems worth while to direct attention to the last four lines of the table, the ratios varying between 1:16 to 1:29. They are all residual combined carbon ratios after slow cooling of fairly well-saturated compounds. While, if we take the 0.60 carbon, which gives a definite acicular structure with fused calcium chloride, we get a ratio of 1:35.4, whereas 0.43 per cent. carbon specimen, which does not give a definite acicular structure, gives a ratio of 1:49.5.

A general review of the table of ratios shows that carbon combines with iron in all proportions up to 4.81 per cent., and

PLATE V.



25 diameters.
Cement Bar.
Carbon 1.8 per cent.
Etched with Calcium Chloride at bright
red heat.



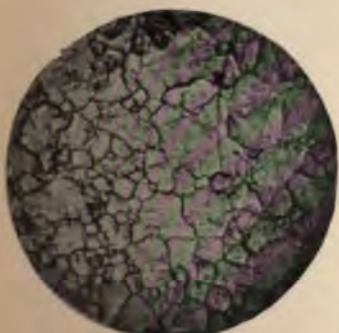
200 diameters.
Cement Bar.
Carbon 1.8 per cent.
Etched with Calcium Chloride at bright
red heat.



200 diameters.
Cement Bar.
Carbon 1.0 per cent.
Etched with Calcium Chloride at bright
red heat.



200 diameters.
1/4-in. bar.
Carbon 0.60 per cent.
Etched with Calcium Chloride at bright
red heat.



200 diameters.
1/4-in. bar.
Carbon 0.43 per cent.
Etched with Calcium Chloride at bright
red heat.



200 diameters.
2-in. billet.
Carbon 0.10 per cent.
Etched with Calcium Chloride at bright
red heat.

that iron produces on cooling a decomposition or crystallisation product having the formula of Fe_3C . There is thus no evidence sufficiently strong to indicate the formula of any other definite carbide of iron.

In conclusion, I wish to record my thanks to Messrs. Arnold, Seaman, and Stead for kindly supplying me with samples of steel, and to Mr. Stead for valuable instruction in metallo-micrography and photo-micrography.

DISCUSSION.

Mr. G. J. SNEIUS, Vice-President, said that the members were greatly indebted to Mr. Saniter for his very excellent, practical, and most important paper. He hailed it with great satisfaction as bringing them back to a little simplicity in regard to carbon compounds of iron. He had been almost frightened at the great number of carbon compounds which some of their friends were anxious to establish as existing in connection with iron. He thought the result of the paper went to prove that while there might be, and possibly was, one very definite compound of carbon and iron, namely, Fe_3C , probably that was the only one that existed. He had always looked upon the action of carbon in relation to iron as one of solution mainly, and he thought all the evidence went to prove that carbon was dissolved in iron up to a certain point. All his experiments quite agreed with those of Mr. Riley and Mr. Saniter, that the saturation-point of iron and carbon was certainly below 5 per cent.; and he thought it was not far from the figure which Mr. Riley had mentioned—about 4.8. While iron might only be able to dissolve carbon up to that point, it was quite possible that a definite compound might be formed between the carbon and the iron Fe_3C , and that the remainder might be simply held in that very weak state of chemical combination which was termed solution. He did not at all see how they could explain the separation of graphite from pig iron if they assumed that the whole of the carbon existed as a definite compound. He did not see what force there was to separate free carbon from the iron on the solidification of the body if it existed as a definite compound; but if it existed merely in solution, or if the bulk of it existed merely in solution, there was every reason for the ordinary action of solutions taking place, namely, that as they got colder some of those substances which they held in solution separated out.

With regard to ordinary chemical solutions, saturated with a given salt, some of them would still retain the whole of the salt solution on cooling, but a great many of them would deposit a portion on cooling. He thought that all the facts they knew in relation to iron and carbon pointed to that same action.

It appeared to him that there were some bodies which had a greater power of holding carbon in solution than iron, and he thought that manganese was one of those bodies. They knew that the compound of manganese, carbon, and iron contained more carbon than ordinary pig iron. He believed that Mr. Riley would bear him out when he said that some compounds of carbon and manganese contained up to over 6 per cent. of carbon.

He did not think that much had been done with regard to the compounds of carbon and nickel, but he thought it was a very interesting study, which might well be followed out.

There was one very curious thing in connection with the study of the solution of carbon in those metals, namely, that the recent experiments of Moissan, the French chemist, had shown that it was from a solution of carbon in iron that they were able to produce artificial diamonds. Professor Roberts-Austen had shown the other day, at a meeting of the Royal Society, some very small diamonds that had been separated from pig iron in that way. The process was simply to fuse the pig iron containing the carbon at a very high temperature, the temperature of the electric arc, and then suddenly to chill it so as to bring immense pressure to bear upon the body, and thus cause the separation of the carbon in a crystalline form. He would throw out the suggestion that if it was possible to separate the carbon from a solution containing, say, under 5 per cent. of carbon in that way, it should be more feasible to arrive at the same result if they used a body containing a larger proportion of carbon, say ferro-manganese, which contained more carbon. It might be interesting to follow that line of study up by trying what would be the result of using the nickel compound with carbon.

Then there was a point of very great importance in the paper, the suggestion thrown out by Mr. Saniter that the crystalline carbide of iron was the cause of the hardness of steel. He thought that was quite feasible. It was perfectly clear that if they had a carbide of iron in solution in the molten iron, and by chilling crystallised it, the crystalline forms would be much harder than the amorphous form. The diamond, of course, was the perfection of hardness, the hardest substance they had, and it was one of the most definite crystalline forms. It was quite probable that if the carbide of iron did crystallise in that

way—and there was every reason to believe that it did—he thought it really opened up an explanation of the cause of the hardness of steel.

He should like to call attention, in connection with the paper, to one analysis that was there mentioned in a very modest way. Mr. Saniter had drawn no particular attention to it, but he (Mr. Snelus) thought that it was of the utmost consequence to the Iron and Steel Institute. Mr. Saniter gave the analysis, and simply called it pure iron. He thought the Wigan Coal and Iron Company should be complimented on the making of that wonderfully pure material. In the paper the author called it, "Wigan 'Pure' Cement Bar."

Turning to the analysis, it would be seen that it contained no silicon or silica. Of course, silica would only be there in the form of slag, an extraneous body. The phosphorus was down to 0.008, which, he thought, was a very remarkable result. They all knew that Swedish iron owed its property of taking a keen cutting edge to its low contents of phosphorus and other elements, and his (Mr. Snelus's) experiments showed that about 0.02 per cent. of phosphorus was the average of ordinary Swedish steel. If, therefore, the Wigan Coal and Iron Company, under Mr. Saniter's and Mr. Percy's management, could with regularity get down to 0.008 of phosphorus and 0.014 of sulphur, he thought they had got hold of a material which was of the utmost value. Perhaps Sir William Anderson would allow him to mention a little chat that they had together at lunch on the previous day. They were talking of the question of the analysis of metal, and Sir William Anderson assured him that at Woolwich they now depended upon chemical analysis for determining the quality of their metal,—that they went by chemical analysis entirely, and had not been misled by it. He thought that was a very important point as bearing on the subject under discussion. Here was a body showing the most perfect chemical analysis of any metallic iron that he had ever seen. He was rather surprised that more had not been done in the same direction. He had on several occasions suggested that the purest iron could be made by the basic process, and that from it they could produce the very best tool steel and the very best cutlery steel. He was informed that

that very steel was used for electrical purposes where very high conductivity was required, and that owing to its purity it had those very important properties. He thought, therefore, he should not be considered out of place in calling attention to that very important substance which Mr. Saniter had so modestly passed over, simply giving the analysis, and never calling attention to it. He thought the paper was an extremely important one. He had read it with some care, and had come prepared to say a little upon it with the object of bringing it more prominently before the members, and directing attention to some points which had occurred to him in reading it.

Sir WILLIAM ANDERSON, K.C.B., F.R.S., said he was not prepared to speak upon the paper, which was one requiring a good deal of thought and consideration, and he had only just heard it for the first time. He would ask permission, however, to refer to the statement just made by Mr. Snelus, and to make it a little more clear. It was not quite exact to say that at Woolwich steel was bought on chemical analysis entirely. Steel forgings for gun purposes were still bought on mechanical tests, but as they had given up making gun-steel at the Arsenal, they now purchased a large number of ingots out of which forgings for guns and other purposes were made—perhaps at remote periods from the time of the purchase,—and those ingots were accepted entirely on chemical analysis. So far the course had been justified by results, because the forgings made had always responded accurately to what was expected from the mechanical tests. No doubt the firms which supplied the ingots were also engaged in providing gun forgings, so that they knew exactly what was required. Still he could not help thinking that what he had stated was a great triumph for chemical investigation, showing the accuracy with which the properties of steel could be foretold from its chemical composition. Of course it was a matter of great importance that ingots which might not be used for two or three years, but which had to be paid for at once, should not become a public loss by turning out to be unsuitable. It was rather a bold experiment to lay in a large stock entirely on the strength of chemical analysis, but the result had justified the course pursued.

Mr. R. A. HADFIELD, Member of Council, felt sure that the members would consider themselves greatly indebted to Mr. Saniter for his very excellently prepared paper, especially because it dealt with a new field of investigation, viz. the examination of fractures and structures of iron and steel at high temperatures. He thought that it was a point that had not been thoroughly looked into before. Dr. Wedding, four or five years ago, in a paper which he had contributed to the Institute, suggested that very great advantage might be gained if they could study this point. He was therefore specially glad to find Mr. Saniter first in this new field. Mr. Saniter had referred to the formation of a graphitic carbon in saturated carbon-iron compounds, and he had said that it would not be possible to precipitate graphite if the metal was free from silicon. No doubt silicon had a great influence, but he thought if they could get a pure carbide of iron, and treat, that is, anneal it by the process used in the preparation of malleable cast iron castings, the graphite would be precipitated even if silicon was entirely absent. On the same page Mr. Saniter had referred to some samples of cast iron which gave a grey fracture on the outside and a white one in the centre. He was glad this had been mentioned, because he had made a number of specimens two or three years ago which puzzled him considerably.

Had Mr. Stead been present, he would have asked him to deal with the subject, for he (Mr. Hadfield) had given him some small specimens which were now under examination. He melted white Swedish iron (4 per cent. carbon, 96 per cent. iron) in a clay crucible and allowed it to cool down slowly, and, to his surprise, a fracture (Plate VI.) resulted somewhat like a Christmas plum-pudding, that is, the graphite was scattered all over the white iron fracture in little centres or nuclei, and presented a most curious appearance. It was difficult to imagine graphitic formation of that kind in a mass of white iron in which silicon was practically absent, not more than 0.10 per cent. In the paper Mr. Saniter referred to the fact that the saturation-point of the samples of pure iron wire that he had treated was about 2.95 per cent., but he (Mr. Hadfield) could not understand why it should not be possible to get as large a percentage of carbon by the means used, if sufficient time had been given. It was

possible to produce iron-carbon compounds by fusion containing 4 per cent. of carbon, and therefore he did not see why it should not be also possible to produce a specimen of higher carbon than that quoted by Mr. Saniter, if more time had been given. He thought there ought to be as high a combination when adding carbon by what was really a cementation process as by fusion.

Another important matter had been referred to in the paper. Mr. Saniter had there mentioned facts dealing with the long-continued controversy as to iron being able to assume another form, but he had not mentioned one point which Mr. Osmond had claimed, and which he believed was the great stumbling-block between those who represented the carbonists and Mr. Osmond and Professor Roberts-Austen, who represented the opposite side. It was that electrolytic iron could be made as hard as hardened carbon steel—he believed Mr. Osmond used the words “adamantine hardness.” He thought there were many on the carbonists’ side who would not object to Mr. Osmond’s statement as to allotropic modifications of iron, if it was made perfectly clear that there was no form of iron possessing adamantine hardness unless it was combined with carbon. The carbonists thought that there must be some carbon present before they could get any hardness at all resembling that of hardened carbon steel. He did not so much care how the allotropists explained the characteristic of hardness if they would only admit that point, but so far they had not done so. In the paper were given some most important conclusions regarding the great influence of carbon upon iron, which, after the laborious research work of Mr. Saniter, were specially entitled to consideration, namely, that he considered there was a definite chemical change or combination of carbon with iron. It appeared to him that Mr. Saniter’s paper more distinctly than ever emphasised the fact that the existence of a β or hard condition of iron had not been proved, or that it was the cause of the “adamantine hardness” obtained in hardened carbon steel, and therefore carbon did not play a secondary part; in other words, that such hardness as was claimed by the carbonists, and as now emphasised by Mr. Saniter, “was due to an attenuated carbide of iron of great hardness.”

Mr. F. W. HARBORD congratulated Mr. Saniter on his very interesting and important paper, which had certainly broken new ground. He himself, although considering there was very distinct evidence of allotropic modifications of iron, had kept an open mind as to how far the hardening of steel was due to such allotropy, and how far it was due to carbon *per se*, and he welcomed all experiments which threw any light upon this important subject. If Mr. Saniter's experiments were confirmed, the evidence appeared to him to distinctly support the carbon hardening theory, and no doubt this suggestive paper would lead to a great deal of useful work.

Mr. JEREMIAH HEAD desired to say a few words from the point of view of those who used iron and steel for constructive purposes. What they always wanted was a metal which was absolutely reliable—a metal on which they could depend in the matter of its tensile strength, its ductility, and its elastic limit. They wanted to feel confident that it would always behave exactly as it ought to behave. To get these qualities, they must have as nearly as possible a homogeneous material. The application of micro-photography to the structure of steel by Messrs. Sorby, Arnold, Sauveur, Stead, Saniter, and others had proved that commercial mild steel of even the best brands was by no means absolutely homogeneous. It was a compound of pure iron crystals interlarded with the distinct substance called carbide of iron; and the physical as well as chemical properties of metallic iron and iron carbide were somewhat different. Now, if they made a rope which depended for its strength partly on hemp fibres, and partly on fine steel wire interwoven therewith, they knew that it would be less reliable than if the rope were made entirely of hemp or entirely of wire. When a stress was put upon it, the hemp would stretch, and throw the bulk of the stress upon the wire until that broke, and then, having lost the support of the wire, the hemp would give way; therefore the compound rope, though it would bear a higher ultimate stress than the hemp by itself or the wire by itself, would be much less reliable than a rope entirely composed of one or the other element. It appeared to him that micro-photography had shown that structural steel was somewhat of that nature. What they

wanted was to get it more homogeneous, and therefore more reliable, even if they had to sacrifice some tensile strength. He did not think that users of steel for constructive purposes were deeply interested in steel containing carbon up to the saturation-point, which appeared to be 4.8 per cent. What they were mainly concerned with was steel containing from 0.1 up to about 0.4 per cent., which he thought covered almost the whole range of steels in structural use. They knew that in proportion to the increase in the percentage of carbide between those limits, ultimate tensile strength and elastic limit were increased, and ductility was decreased. Not only so, but with decrease in ductility, certainty of behaviour, that is, reliability, was also apt to diminish.

Therefore, if they wanted maximum reliability, they would perhaps secure it best by confining themselves to steels containing a minimum of carbide, or any other foreign substance; in fact, to the use as nearly as it could be obtained of chemically pure iron. His object in making these remarks was to encourage men like Mr. Saniter, who devoted so much time, trouble, and expense to original chemical and metallurgical research, to keep in view, as far as possible, the physical tests and the actual conditions which were required in commercial work. Interesting as original researches were to them all, academically speaking, and unbounded as were the effects which they might produce in the future, they should always keep an eye to the practical requirements of the present, and of those who were responsible for the safety of the gigantic metallic structures of modern times.

Mr. JAMES RILEY, Vice-President, asked permission to say a word or two with regard to the points raised by Mr. Head, as he was anxious that nothing should go forth which might mislead in the least degree. It did not follow that because their friends were pointing out that there were various constituents in steel as they knew it, it should therefore have its reputation injured because it was not quite what Mr. Head had described as homogeneous. It appeared to him that if they knew there were definite characteristics of steel of certain composition, and that those characteristics could always be relied upon and were

uniformly the same, there was no good reason why they should have any fear because their friends were telling them how the "pudding," if they liked so to call it, was built up. He was sure that Mr. Head, speaking as he did with the authority he possessed and the influence he exerted in their meetings as well as outside, would not like to say in that place or anywhere else anything that would be detrimental to the character of the metals that were produced, or that would in the least degree cause any anxiety as to the use of those materials. He simply rose to make those few remarks in order to guard against the possibly detrimental influence which he was sure Mr. Head would not in the least desire to encourage.

Mr. T. H. BAILEY felt some diffidence in making any remarks on the subject, but he might mention that, as no doubt the President was aware, he had had some experience in dealing with cast and wrought iron and steel with the electric current. He had erected an installation in order to repair iron and steel castings at different times, and thus save the time lost in obtaining new ones. The current used was 140 volts, and from 400 to 800 amperes, and it had most extraordinary effects upon the material. In only one case of casting, that of the cross-head of an old pumping engine, were they able to repair it so that it could be machined afterwards. The cast iron retained its soft character, and they could turn it up in the lathe: in the case of all the other castings, they utterly failed to do anything with them, as they were hardened to such an extent that no steel tool would touch them.

With regard to the question of the use of aluminium, this had been tried, and he should like Mr. Saniter to know that they found that by using aluminium the steel was hardened so that they could not touch it. They did not measure the quantity used, simply melting it with the current.

He also had an idea that the carbon poles or terminals in wasting carbon had a great effect upon the metal in hardening it. In order to test that, he took out the carbon point and put in a steel terminal, and they obtained just what he expected, softness of the metal used instead of the hardness. He thought it would be useful for the members to know these details,

because he believed that with the electric current a great deal more could be found out about the combination of carbon and iron than by any other method. There was on the table a sample of some of the steel treated in this way, and it would be seen that it was perfectly soft, having been filed and drilled. He had placed it under a microscope, and it showed the carbide portions very clearly.

MR. SANITER, in reply, thanked the members for the kind way in which they had received his paper. There were not many questions to be answered, as every one appeared to be practically on the same side. Both Mr. Snelus and Mr. Riley had spoken of temperature influencing greatly the liberation of graphite. He thought it was so with compounds in the solid state, but in the case of any compound which was liquid and solidified, he thought it had very little influence. The rate of cooling had more influence than the original temperature, and also the presence of small quantities of silicon; for in the table given in the paper they had got down to 0.03 per cent. of silicon, and it gave graphitic carbon in a slowly-cooled button, and 0.03 was not far off nothing. 7.3 per cent. was, he believed, about the highest carbon in ferromanganese, but whether it would be a sufficiently strong material to give the high pressure required to make diamonds by the Moissan method was doubtful, while pig iron was so much stronger, and gave the increased pressure.

Mr. Snelus had kindly referred to the pure quality of steel made by the Wigan Coal and Iron Company. They had made a good many hundred tons of that quality, and they were making more to suit the demand.

MR. SNEBUS said that the Wigan Coal and Iron Company had supplied a mining company with which he was connected with some of their steel four years ago. They still used it, and could not get anything equal to it.

MR. SANITER said he thought that Sir William Anderson had given chemists a very good testimonial, for which he begged to thank him. Mr. Hadfield had referred to the pure carbide and the action of silicon. He (Mr. Saniter) had not intended to say

that saturated iron and carbon without silicon would give a white iron : he said that it possibly might do so. If there were absolutely no silicon, there might be no graphite liberated. That was a point that had yet to be proved. Mr. Hadfield had also referred to the cementation experiment. It was possible that if, instead of heating it twenty-one hours, it had been heated for as many days, it might have got up to the same level as in the fusion experiment ; but even with 2.95 of carbon they had a half per cent. of graphite, and it was a question whether that formation of graphite would go on until it had got to the saturation-point of the fusion compounds. He quite agreed with Mr. Hadfield that the crux of the whole dispute between allotropists and carbonists was not the allotropic modification of iron, but that the allotropists wished them to believe that the allotropic modification of iron was hard, and was the cause of the hardness of chilled steel.

With reference to Mr. Head's remarks, it was no doubt quite right, as he had said, to keep an eye on practical utility. Sometimes science was behind practical utility, and only built up theory after the facts had been found out. Sometimes science went ahead of practical utility, and found out the facts on which practical utility was based. It was, therefore, as well to keep an eye on both. He thought that Mr. Bailey was quite right in ascribing the hardness of the material he had dealt with to the carbon poles of the anode. If Mr. Bailey would point out or give a paper on the subject of the direction in which electricity might be used for investigating the constitution of steel, it would, no doubt, be of great interest to the Institute. He again thanked the members for the manner in which his paper had been received.

CORRESPONDENCE.

Professor HENRY M. HOWE, of Columbia University, New York, sent the following contribution to the discussion :—

Mr. Saniter's procedure is a very bold and, so far as I know, wholly original one. It certainly commands our hearty admiration. It seems to me of even greater value for the important

lines of investigation which it suggests than for the welcome results which he actually lays before us.

His observation that the impurities found in the cement bar are found in like proportion in the cementite itself is important. It reminds us of Mr. Osmond's observation that a small quantity of silver dissolves in copper, and conversely that a small quantity of copper dissolves in silver, and that a solution of a small quantity of either of these metals in a great excess of the other appears under the microscope to be absolutely homogeneous.

I do not feel sure that I follow Mr. Saniter's reasoning which leads him to the conclusion enunciated in a paragraph near the end of the paper, beginning "This method of investigation." As I understand him, his reasoning is as follows:—

First premise.—The acicular structure of martensite is due to the presence of a carbide.

Second premise.—The hardness of martensite is due to its acicular structure.

Conclusion.—The hardness of martensite, and hence the hardening of steel, is due to the presence of carbide.

This conclusion depends as completely on the second as on the first premise, and unless the second premise is granted the conclusion cannot stand. Now I would ask Mr. Saniter to point out the evidence and reasoning supporting this second premise. I confess that I do not see any, and hence the conclusion seems to me unwarranted. Indeed, his own micrographs, on the beauty of some of which he is to be heartily congratulated, seem to make against this second premise. Thus, his steel containing 0.43 per cent. of carbon seems from his micrograph to be wholly free from the acicular structure, and he indeed says that this structure is only faintly marked in this steel. Yet this steel ought to be capable of intense hardening. That is to say, its martensite should be intensely hard, although, according to this micrograph, almost free from acicular structure. This consideration, of course, is not conclusive, but it seems to me that it makes strongly against the second premise, in that steel of 0.43 per cent. carbon differs from that of 1 per cent. carbon to a far greater degree in the strength of the acicular structure than in its hardening power, i.e. than in the hardness of the martensite; so that the hardness of the martensite does not seem here proportional to the acicu-

lar structure. If, then, the acicular structure is not a measure of the hardness of the martensite, may we not justly question whether it is its cause?

In regard to the saturation of iron and carbon, it may have escaped Mr. Saniter's attention that Moissan found 8.75 per cent. of carbon in the salamander of a blast-furnace; but this may be hardly a fair case.

It is very interesting in the present connection to look at Moissan's results in the preparation of carbide of iron. He found that when pure iron was heated with carburised sugar in the electrical furnace, it became less and less liquid as the temperature rose. At a temperature near that of the melting-point of titanium the contents of the crucible became so viscid that nothing would run out even when the crucible was turned over. He appears to refer this to the formation of a great quantity of carbide at this extremely high temperature, and to consider it as parallel with the observations of Deville and Debray, that when silver which had been volatilised was cooled suddenly in contact with the air, the silver collected contained also oxide of silver, which thus forms at a temperature far above that of its usual decomposition; and parallel also with the results of Troost and Hautefeuille, that ozone, which is destroyed so easily by a slight elevation of temperature, can be produced between 1300° and 1400° C. He adds, "We believe that the direct preparation of carbide of iron has added a new example to these curious phenomena. In effect, if we suddenly cool cast iron saturated with carbon, we shall obtain a metallic ingot rich in iron carbide. The percentage of combined carbon will rise to 5.25 per cent." (*Comptes Rendus*. As I write this from the seashore, I cannot give the reference with confidence, but I believe it to be page 719, first volume for 1879.) In this view the saturation-point of iron for carbon rises as the temperature rises from the melting-point towards that of the electric arc.

Mr. F. OSMOND considered that, with reference to the maximum carburisation of liquid iron, the important work of Boussingault on that subject should be borne in mind.* That

* "Etudes sur la Transformation du Fer en Acier par la Cémentation," Paris, Gauthier Villars, 1875.

chemist came to the conclusion, more than twenty years ago, that the limit of carburisation corresponded to 4.10 per cent. of carbon (Fe_3C). As a matter of fact, it was now quite evident that a compound of that definite formula did not exist: the alloy, which contained (about) 4.10 per cent. of carbon, was the *eutectic* alloy of liquid iron and Fe_3C . Similarly, there was no evidence that a carbide of iron other than Fe_3C was formed during the cementation of solid iron. The limit of carburisation of the solid iron at a given temperature * was the solubility of Fe_3C † in the solid iron at that temperature. That limit appeared to correspond to an amount of carbon of about 0.9 per cent. at the temperature of recalescence, which was about 670°C .; it increased when the temperature was raised. If each limit of carburisation represented a definite compound, there should be an infinite series of such compounds, which was in contradiction to the nature of definite compounds. In practice, the limit of carburisation at a given temperature was not easy to determine experimentally by direct cementation: the temperature should be maintained rigorously constant throughout the entire length of the experiment; if there was a variation of temperature, even of small amount, each lowering might cause a precipitation of cementite and the initial deposition could be increased by oscillating the temperature. It was a usual process for effecting the crystallisation of salts. But the cementite thus isolated during cementation should be subtracted from the total cementite found after cooling. The dissociation of Fe_3C and the possible formation of graphite further complicated the phenomena.

* In the same way, to define the solubility of a salt in water, it is necessary to give the temperature.

† The statement that steel at a red heat is essentially a solution of Fe_3C in solid iron does not presuppose, as Mr. Saniter and Mr. Royston appear to have understood it (*Journal*, 1897, Part I. pp. 189 and 191), that Fe_3C exists totally as such in the solution, but only that steel at a red heat is a solution which allows Fe_3C to be deposited during cooling.

The state of steel at a red heat raises two very different questions:—

(1.) Is steel at a red heat a solid solution or not? The opinion of the writer on this point has never varied.

(2.) If the steel at a red heat is a solution, is the carbon in it free or combined? On this second point the writer has modified his opinion. After having thought that the dissolved carbon was free, he is now disposed, from the recent results, to admit that a fraction of dissolved carbon may remain combined with iron in the form of dissolved Fe_3C . But this second question is far from being solved: it involves the larger question of the constitution of solutions and the theory of *ions*. It is a subject of pending and controverted investigations.

The process of etching at a red heat for the study of micro-structure was in itself interesting. However, as according to the author, the calcium-chloride attacked the carbon more rapidly than the iron, the structure obtained for any sample of steel was not necessarily that of the sample, but that of the less carburised steel which formed the surface of the metal at the end of the etching. Fig. 5 appeared to indicate that that was the case, as the structure, so far as one could judge from a print, indicated rather a low carbon steel than metal containing 0.43 per cent. of carbon. Whilst admitting that that objection, which was one of principle, might be unfounded, it was necessary still to be certain of the delicacy of the method before drawing definitive deductions. Thus the author appeared to experience some embarrassment in concluding, for he remarked: "It will be observed that Nos. II. and III. exhibit a very characteristic structure, which appears to consist of acicular crystals, which show a marked tendency to form triangles. No. IV., 0.6 per cent. carbon, shows this acicular structure strongly, while in No. V., 0.43 per cent. carbon, it is only faintly marked, and in No. VI., 0.1 per cent. carbon, it is entirely absent. The dark network on all of the plates is the ordinary granular junctions, which are well brought out by this method." It would appear from that passage that the structure of steel at a red heat varied progressively when the carbon decreased from 1.80 per cent. to nil. How was that reconciled with the following statement elsewhere in the paper: "This method . . . gives strong evidence that 0.6 per cent. carbon or upwards causes, at a bright red heat, a *radical** change in the structure of iron. . . ."

Farther on the author remarked: "These acicular crystal are, in my opinion, an indication of a *definite* carbide of iron existing in steel at a bright red heat." And further he stated: "A general review of the table of ratios shows that carbon combines with iron in *all* proportions up to 4.81 per cent."

It would be useful for the discussion if Mr. Saniter would kindly state his views more definitely.

Mr. Osmond really saw no reason for modifying the conclusions at which he had arrived, that the triangular forms of

* The italics are the writer's.



FRACTURE OF WHITE SWEDISH IRON.

The black patches represent spherical graphitic formation shown in transverse section.



martensite represented the octahedral crystallisation of gamma-iron. If the figures of the author did not show these triangular forms in low carbon steel, it did not follow that they did not exist, but only that the author had not seen them, either because his process did not reveal them in this case, or because the etching had been too strong, or because the magnifying power he employed was too low in relation to the dimensions of the needles at the bright red heat. In fact, steels of different carburisation heated to the same temperature were not exactly comparable. The presence of carbon facilitated the crystallisation of iron, and to bring the crystals to a degree of sharpness which allowed them to be shown, it was necessary to heat irons to a much higher temperature than steels. In Swedish iron, which had been subjected to incipient fusion, the writer had obtained the triangular figures of the octahedron so fully developed that they were visible under a lens, and almost to the naked eye.

Mr. ALBERT SAUVEUR (Boston, Mass., U.S.A.) noted that in his interesting paper on carbon and iron, Mr. Saniter stated that his residue, since the steel used contained 1 per cent. of carbon, must include 11 per cent. of free cementite. This was on the assumption that the carbon exceeding 0.89 per cent. must exist as veins of cementite. The statement was somewhat inaccurate, and as the same error had been made recently by other writers, it might not be out of place here to call attention to it.

While it was true that steel containing very little other impurity required about 0.89 per cent. of carbon to be saturated, it was obvious that it did not follow that only the carbon in excess of 0.89 per cent. existed as free cementite. While pearlyte (the only constituent of saturated steel) always contained 0.89 per cent. of carbon, it was only when the steel contained 100 per cent. of pearlyte that this represented 0.89 per cent. of carbon *in the steel*. If the metal contained some free cementite, then the amount of pearlyte, and therefore the proportion of the total carbon included therein, decreased correspondingly.

One per cent. of carbon yielded very nearly 15 per cent. of Fe_3C , leaving 85 per cent. of carbonless iron in the steel.

The iron (ferrite) united with a certain amount of this carbide to form pearlyte, as follows:—

$$\begin{array}{ccc} \text{Fe.} & \text{Fe}_3\text{C.} & \text{Fe.} \\ 86.65 & : 13.35 = 85 & : x. \end{array}$$

for if pearlyte contained 0.89 per cent. of carbon, it was made up of 86.65 per cent. of ferrite and 13.35 per cent. of cementite. The equation gave very nearly 13.1 for the value of x , leaving an excess of cementite of 1.9 per cent. In round numbers, Mr. Saniter's steel was made up of 98 per cent. of pearlyte and 2 per cent. of cementite. About 13 per cent. of his residue, therefore, must be derived from the free cementite existing in the steel.

The structural composition might perhaps be calculated more rapidly as follows:—

Let x be the percentage of pearlyte, y the percentage of cementite in the steel; then

$$x + y = 100.$$

The pearlyte would contain $\frac{0.89x}{100}$ per cent. carbon, the cementite $\frac{6.67y}{100}$ per cent. of carbon; therefore

$$\frac{0.89x}{100} + \frac{6.67y}{100} = 1 \text{ (percentage of total carbon).}$$

These two equations give

$$x = 98.1 \text{ and } y = 1.9$$

or roughly 98 per cent. of pearlyte and 2 per cent. of cementite.

He would like to offer a few remarks regarding Mr. Saniter's microscopical investigations. In the paper it was stated that the structure made apparent by the etching was, without doubt, that existing at a bright red heat. He (Mr. Sauveur) did not see how such could be the case, for if it were so, it would be necessary to conclude that the chloride of calcium remained passive until the metal had reached the temperature of the bath, becoming passive again during the cooling. As a matter of fact, however, the metallic surface must be acted upon as soon as it came in contact with the fused chloride, and the action must continue, although possibly with varying intensity, as long as the steel remained in the salt. But as the metal was

gradually heated, however rapidly, to the temperature of the bath, its structure, as was well known, changed constantly; the metal passed its critical point where such important structural modifications took place, and all the while the action of the chloride was being exercised upon the polished surface. So it must be during the cooling, with this difference, that here less time was afforded for action, because the cooling was more rapid than the heating.

It would seem, therefore, that the salt acted upon a constantly changing structure, and that the appearance of the specimen was the result of that very complex action. If he was right, the above considerations could not be lost sight of in drawing conclusions resting upon the appearance of the etched samples. Even if Mr. Saniter's deductions were based upon irrefutable evidences, however, he failed to see that they were at all damaging to the allotropic theory.

It was said by Mr. Saniter that "we therefore come to the point that at a bright red heat iron containing 1 per cent. carbon has a totally different structure from iron containing 0.1 per cent. carbon, and that this difference of structure is due to the carbon *per se*." He did not doubt but such was the case, and he believed that every allotropist also would expect the structure of two such steels to be totally different at any temperature, and might even concede that such difference was due to the carbon *per se*; but he did not see that the fact carried with it any refutation of the allotropic theory.

He likewise failed to perceive that Mr. Saniter's very interesting and suggestive experiments brought any support to Professor Arnold's assumption of the existence of a very attenuated carbide of iron at a high temperature.

Mr. Saniter argued that since the acicular crystals exhibited by high carbon steels etched in fused calcium chloride were not found in soft steels, they were an indication of the existence of a definite carbide at a bright red heat, for if they were made up of allotropic iron they would be found as well in very low carbon steels. As a matter of fact, it only indicated that the presence of a sufficient amount of carbon was necessary in order to induce the formation of those acicular crystals, but it gave us no information regarding their composition, nor was it opposed

to the allotropic theory. Indeed, Mr. Osmond in describing the structure of martensite,* attributed it "to the crystalline organisation, *under the influence of carbon*, of one of the allotropic varieties of iron." And might he not be permitted, while the matter of evidence in favour of the existence of Professor Arnold's carbide Fe_{24}C was again put forward, to allude to some recent remarks of Mr. Saniter and of Mr. Stead in the discussion of Mr. Hogg's paper on "Missing Carbon."†

Both metallurgists saw in Mr. Hogg's results evidences supporting Professor Arnold's theory. In a contribution to the same discussion he had endeavoured to show that all the missing carbon was "derived" from the carbon present in the martensite. This was not contested, and Mr. Hogg, when he alluded to some of his remarks as speculations, did not, he believed, have this point in mind, unless he thought that some of the missing carbon might come from the segregated carbide Fe_3C (cementite) itself, which the writer hardly thought he did. The only speculative statement in the writer's remarks was to be found in the suggestion that the carbon in martensite might be present as the carbide Fe_3C in an extremely minute state of division, which would account for its volatilisation when treated with cold dilute acids. He was very far from insisting that such was the case, only he thought the suggestion worthy of further inquiry.

Coming back to Mr. Saniter's and to Mr. Stead's remarks, they both based their calculation, exactly as the writer did, upon the fact that no missing carbon could be derived from the free cementite (segregated Fe_3C) present in the steel, and therefore that it all came from the martensite, and they naturally found that the amount of missing carbon was proportionate to the martensite carbon. They could not find anything else. They then *assumed* that martensite was the carbon Fe_{24}C (or rather included such a carbide), and concluded that their results supported such a view.

It would be seen, however, that they left them exactly where they were. The query, what was the chemical constitution of martensite? still remained unanswered. Was it, as Professor

* *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, 1895, p. 493.

† *Journal of the Iron and Steel Institute*, 1896, No. II.

Arnold contended, a carbide of the formula Fe_{24}C , diffused or not throughout a matrix of iron? The writer did not see how the fact that Mr. Hogg's missing carbon was derived only from martensite carbon could constitute any indication of the accuracy of the latter view, and the results of Mr. Stead and of Mr. Saniter were merely a sequence of that fact; they were not more conclusive of the existence of the particular carbide Fe_{24}C than they were of the existence of Fe_3C in martensite, or of *any other* carbide containing *not less* than 0.89 per cent. of carbon, or indeed of the presence of diffused carbon.

Referring again to Mr. Saniter's contention that the structure made apparent by his etching was that existing at a bright red heat, Mr. Sauveur wished to modify somewhat the view he expressed upon that matter. After further consideration, he now believed that Mr. Saniter was right, because, while the structure of the steel changed (during the critical range or ranges) on being heated to the temperature of the chloride bath, yet the last impressions left upon the polished surface by the action of the salt, probably represented the structure of the metal at the time of quenching. But, and this was an important consideration, it implied that the metal did not undergo any structural modifications during the rapid cooling of the crucible, for, if it had, the character of the etched surface would have changed correspondingly, and therefore would no longer represent the structure at a red heat. In other words, it implied that the structure of quenched steel was identical with the structure it possessed at the quenching temperature, and, if such were the case, such structure could be revealed more conveniently by etching the quenched specimens; nothing was to be gained by etching it at a high temperature. Of course, calcium chloride could not then be used, and for that reason the appearance of the two etchings (a calcium chloride etching at a red heat and an acid etching of the quenched sample) might not be identical, but they should have the same general character. Indeed, this view was supported by the appearance of Mr. Saniter's photomicrographs and of those of Mr. Osmond exhibiting the structure of martensite; their general character was very similar, and he was inclined to think that Mr. Saniter's acicular crystals in no way differed from Mr. Osmond's martensite needles.

Mr. RALPH G. SCOTT thought that thanks were due to Mr. Saniter for his contribution to the question which all steelmakers were so much interested in—viz., the relations of iron and carbon in steel. He had been specially struck by the succinct and practical way in which he presented the results of his experiments, and the deductions he drew seemed largely justified. His experiment with Fe_3C seemed to prove that a substance which was insoluble in acids, even when in a microscopically small state of division, like *cementite*, became soluble when still more finely divided, as in pearlyte, and lent colour to the opinion put forward by Mr. Sauveur in a recent paper, that free carbon, if sufficiently finely divided, might be acted upon directly by acids with the formation of hydrocarbons. By etching with CaCl_2 , Mr. Saniter showed that Fe_3C existed in steel at a bright red heat, and as the prepared Fe_3C fused into a button without total decomposition, it might exist in the molten state. Whether it be as free carbon or as carbide of iron that carbon was diffused through liquid steel, it seemed to him much the simplest plan to look upon the molten mass as a solution and analogous to an alloy. The great difficulty was to find out what happened when this solution or alloy of liquid iron and liquid carbon or carbide reached its freezing-point (it might very probably have several freezing-points), and then passed through the plastic to the solid condition? He had lately seen, through the kindness of Mr. Osmond, a paper published in 1868 by a Mr. Jullien, entitled "*La Théorie de la Trempe*," which might not be altogether void of interest, although it was written so many years ago. The theory was shortly as follows.

Substances such as iron and other metals with weak powers of radiation tended to crystallise when slowly cooled, and the slower the cooling the more perfect was the crystallisation; quick cooling, on the other hand, tended to render them amorphous. Carbon, with its high radiating power, had a tendency of an exactly opposite nature, slow cooling rendering it amorphous, and quick cooling giving it a more and more perfect crystalline form, the quicker the cooling was carried out. He might mention that he considered graphite *amorphous* carbon. Mr. Jullien contended that by varying the conditions under which a solution of carbon in iron was cooled, one obtained

crystalline iron with amorphous carbon, or amorphous iron with crystalline (diamond) carbon, or any mixture of the above which corresponded to the conditions of cooling.

Since the above theory was advanced two facts with regard to it had been learned :—

(1.) That there was a definite carbide of iron and carbon, Fe_3C , which played a prominent part in giving to steel the special properties it possessed when cold. This Jullien would not admit.

(2.) Professor Moissan had proved that carbon could be obtained in the diamond form from a solution of carbon in iron by very quick cooling, and the molecular pressure induced thereby. This confirmed one part of Jullien's theory.

It seemed quite possible that Fe_3C might have a crystalline as well as an amorphous form, and if it followed the same rule as carbon, it might be allotropic, unstable, and of very much greater hardness than that which was found as cementite and as a constituent of pearlyte.

If, then, there were two substances in steel which assumed an adamantine form on sudden cooling, an indication was afforded of the direction in which an explanation must be looked for of the hardening property possessed by carbon steel when suddenly cooled, and it seemed less necessary to assume the existence of a hard allotropic form of iron.

Mr. J. E. STEAD, Member of Council, considered that the paper of Mr. Saniter gave the result of long-continued labours. The chief points of interest were :—

First, That segregated cementite, such as was found in cement bar, was not readily dissolved or oxidised by nitric acid of 1.2 specific gravity, and that in an actual trial nearly 90 per cent. of the original cementite was left practically unaffected.

He (Mr. Stead) had often noticed in testing drillings of cement steel by the colour method that the last portions of cementite could only be dissolved by the long-continued action of nitric acid 1.2 sp. gr., but he had not made a quantitative determination.

Second, That Mr. Saniter had succeeded by his desulphurising process in making iron as pure as the best Swedish irons, and that instead of having to depend on Sweden for a pure base

for his experiments, he had obtained it entirely from English material.

Third, That the carbide separated by Mr. Saniter contained some phosphorus, but the results scarcely justified the belief that in cement bar high in sulphur and phosphorus these impurities would in such a case be "equally distributed throughout the carbide and ferrite." Further trials were required in this direction.

Fourth, The laws which determined the separation of graphite from solidifying iron, and from solid carbides by heating, required more systematic study. Slight differences in the rate of cooling, the temperature, chemical composition, and pressure, had all to be taken into consideration, and it was most probable that the differences between Mr. Saniter's results and those of Mylius, Foerster, and Schoene were due to differences in one or more of these factors.

Fifth, That Mr. Saniter gave 4.8 per cent. of carbon as the saturation-point of iron, but Moissan had shown that in the electric furnace iron would combine with so much carbon as to form a mass too thick to pour from the carbon crucible, and it was well known that if too much coke were used on a blast-furnace, the iron took up more carbon at the higher temperature than it could retain near the melting-point, and that graphite separated out, and, if time was allowed, it would eventually close up the well or hearth of the furnace. It followed, then, that iron at the higher temperature would carry more carbon than the same after slightly cooling, and it was also probable that, if quickly cooled, it would retain more carbon than the slowly cooled material. Judging from that, and the way the experiments of Mr. Saniter were conducted, it was fair to state that the slowly cooled compound of iron and carbon retained a maximum of 4.81 per cent. of carbon, but that amount was only the residue of what was originally present. In crucible experiments, it was a common thing to obtain buttons covered with a loose layer of graphite, representing what was at one time in combination, but which had been on cooling thrown out of the iron. It would be interesting if Mr. Saniter, in future trials, would pour out on to a metal plate his white hot carbon saturated metal, so as to retain or keep in the

metal all the carbon present at that temperature, and then to determine what the actual quantity was. The reason why in certain qualities of cast metal there should be sometimes an area of white and an area of grey iron side by side was difficult to explain, although it was of common occurrence.

Sixth, It would appear that Mr. Saniter, under certain conditions, managed to get nearly 3 per cent. of carbon in a cement bar or wire. It was probable that a much larger quantity would have been obtained if the temperature had been higher. The presence of graphite on the outside of the wires experimented upon was most interesting, and would lead to the belief that the action between charcoal and solid iron was more complicated than was generally supposed.

Seventh, The results obtained on hot etching were very interesting, the most remarkable thing being the relatively more rapid rate at which the carbide was attacked. In ordinary cold etching, the carbide was last to be acted upon; here the reverse was the case. The explanation given was probably the correct one, for he knew from experience that calcium chloride was capable of holding oxide of iron in solution, and that evidently acted upon the carbon in the hot steel.

Eighth, The fact that because martensite fibres were not developed in soft low carbon steel by the hot etching process did not conclusively disprove the theory respecting the existence of β iron at high temperatures. It did prove that the hot etching was incapable of revealing the presence of martensite in soft quenched steel, whereas by cold etching it was most clearly shown. A steel with 0.1 per cent. carbon, after quenching, polishing, and etching, gave about 80 per cent. of the areas as martensite. It might be argued, from the allotropic point of view, that carbonless iron in the β state would be equally acted upon (say at 900° C.) by calcium chloride, and that the difference observed on treating in the same way high carbon steel must be due to the not absolutely perfect distribution of the carbon, although it would be difficult to explain how it was. In other words, the difference in hot etching indicated a difference of carbon, but it did not touch the allotropic theory.

It was possible to elaborate many theories about iron and steel, but it was dangerous to receive them as truth without a good deal more solid basis than was at present available. Mr. Saniter's ingenious theories, like many others, would no doubt give rise to much thought and work, with results which would lead on to truth.

The PRESIDENT proposed a hearty vote of thanks to Mr. Saniter for his able and interesting paper.

The vote of thanks was carried by acclamation, and the following paper was read, in the absence of the author, by Mr. Wicksteed :—

A PORTABLE RECORDER FOR TESTS OF METALS

BY GUSTAVUS CHARLES HENNING, NEW YORK.

WHEN it is desired to know all about the working of a steam-engine, to study the working of the steam-valves, piston, clearances, &c., the indicator is used; this gives a record on rectangular co-ordinates of travel of the piston, and to the steam pressures throughout the complete cycle. Similarly, if it were possible to design an instrument equal to the indicator in its accuracy, portability, and universality, to record the behaviour of materials from beginning to the end of the test, it ought to be of general utility, and its introduction comparatively easy. It should be complete in itself, readily and quickly applicable to all testing machines, and should be so constructed as to be readily examined for accuracy, and should of course be durable.

A great many recording instruments for stress-strain diagrams have been designed and used from time to time, but all have been found wanting in one or more respects, and not one has been made portable, so that engineers could take it from works to works, and use it without first being compelled to make more or less costly mechanical preparation for its use in each case. Moreover, the instruments in almost every case are so costly, that their general introduction and use became impossible, especially in view of their limited utility. Some of them, otherwise very ingenious, give diagrams on circular co-ordinates which made them practically useless.

Among apparatus used for this purpose may be mentioned those of Wicksteed, Unwin, Kennedy, Barr, Gray, Martens, Olsen, Mohr and Federhaff, and of Grafenstaden, but as they are fairly well known it is not necessary to describe them in this paper. My conception of a practical recorder for testing materials is as follows:—

It must be portable and compact, requiring no extra precautions in adjustment or regulation, and, without having the

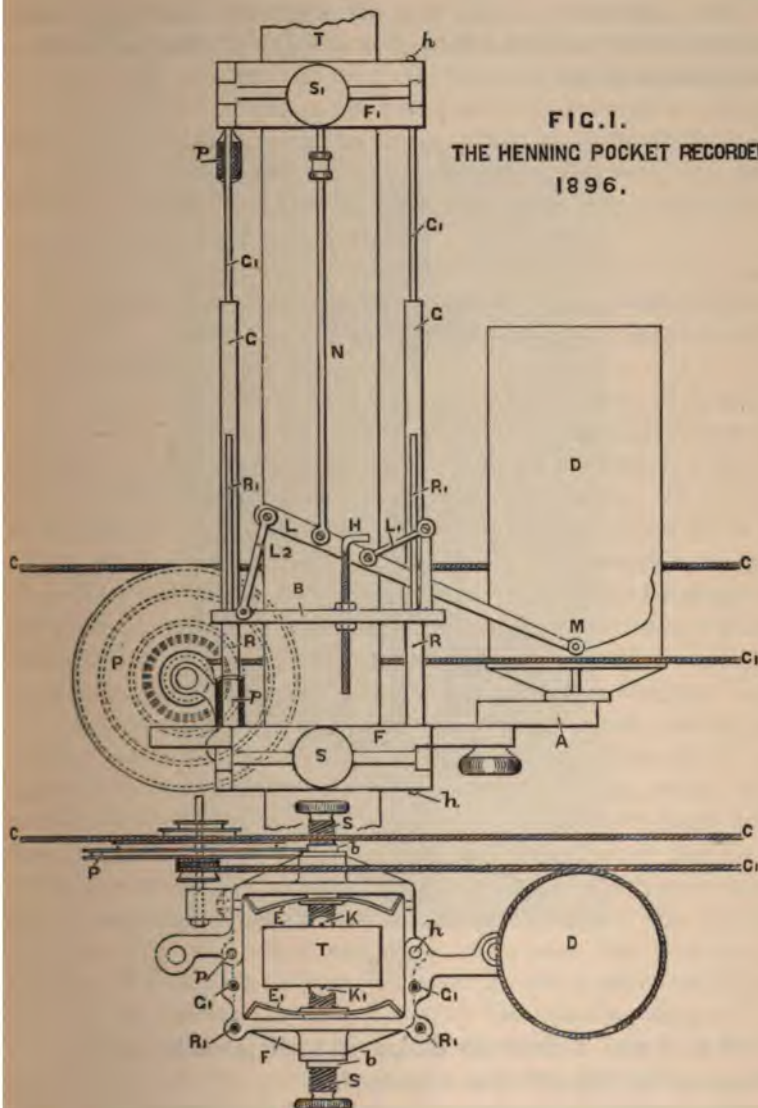
accuracy of an instrument of precision, must be perfectly trustworthy, and as correct as the other apparatus in connection with which it is used. It must cover a wide range of work of short and long, large and small test-pieces, such as are found in general use, and must be applicable to hard and soft materials as well. The apparatus should be applicable in a horizontal as well as in a vertical position. Moreover, it should give a complete record from beginning to end of the test, showing the more important elements on an enlarged, and the lesser, on a natural scale. Thus, while elongations within the elastic limit (yield point) are very minute and must be recorded on a magnified scale which is trustworthy, changes of length beyond this critical point are very large, rapid, and variable; hence measurement with a steel scale suffices, and the record on a diagram may be on actual scale. This change of scale must, however, be positive, controllable, and at a fixed instant or point, and must not introduce errors in the record. In case of materials of slight extensibility, however, the entire record should be on one scale from beginning to end, and the instrument should be so attached that it does not nick or injure the material so as to affect its point of rupture or strength.

As materials under test change shape rapidly and constantly, the instrument must be so designed that this variation does not introduce errors by slipping or tilting or otherwise. Means must be readily applicable which will check the accuracy of the instrument at all times.

As materials are generally tested at the present time, there is no lasting record of the qualities that are claimed to have been found. Moreover, it is well known that many properties of materials cannot be determined except by an autographic stress-strain diagram. The curves obtained vary according to the treatment which the material has been subjected to, and annealing or straining produces such marked results that an autographic record would at once indicate how the material has been treated. Hardening, cold rolling, tempering, and other processes are made apparent by the characteristic features of the curves.

With the use of such a recorder, it would become instantly apparent whether material had been previously intentionally strained to raise the elastic limit, as is well known to have been done. Overheating of material would be clearly indicated by

FIG. 1.
THE HENNING POCKET RECORDER
1896.



the change in the curve, and the general uniformity of any lot of material could be readily determined.

The instrument should also be applicable for compression tests, so as to record the behaviour of material when subjected to compressive stresses.

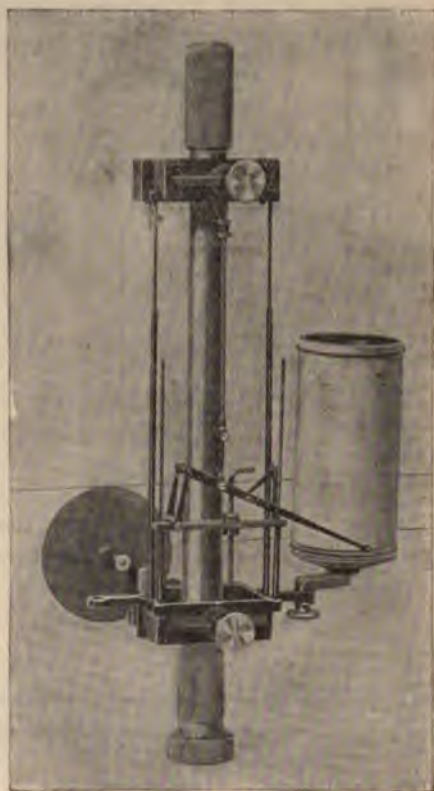


FIG. 2.

Figs. 1 and 2 show my design of such portable recorder, as based on the conception as explained.

Fig. 1 is a detail sketch, while Fig. 2 is a photograph of the completed instrument. Two hinged frames, F and F_1 , are provided with knife-edge pointed screws, S , passing through bushes,

b, which carry springs, *E*. Hinge-pins, *h*, allow the frames to open, while taper plugs, *p*, secure them rigidly together when closed around the test-piece, *T*.

In order that the knife-edges, *K*, in the upper and lower frames bear on the test-piece, *T*, at given known distances, the guide rods, *g*₁, sliding in tubes, *g*, are made of a certain length. These rods, *g*₁, and tubes, *g*, cause the frames, *F* and *F*₁, to recede from or approach each other without changing their parallelism, and prevent any possibility of rocking of the lower frame, *F*, which carries the drum, *D*, on the arm, *A*.

The drum, *D*, must remain at a uniform distance from the axis of the test-piece throughout the test, as any change therein would vitiate the record materially, either increasing or reducing the apparent length of string, *C*.

The lower frame, *F*, also carries a parallel motion, *B L*, as in ordinary use in steam-engine indicators; this parallel motion is actuated by the upper frame, *F*₁, through the connecting rod, *N*, which is interchangeable for longer or shorter pieces. The lever, *L*, of this mechanism carries a pencil or pen at *M*, which draws a line upon the paper wrapped on *D*, either horizontal when the drum is revolved, or a straight vertical line when the drum is stationary, and the frames *F* and *F*₁ approach or recede from each other. If the drum revolve while the lever *L M* moves, any curve may be obtained according to their relative motions. As the possible change of length of material during test, and up to the instant of rupture, is very great, a very long drum would be required to record it on a magnified scale up to that point; the parallel multiplying motion would also become very large and cumbersome. Moreover, the change of length within the yield point is minute, and cannot be recorded to any purpose except on a magnified scale. Now, therefore, to record the elastic changes of length on a magnified scale, and the permanent changes on a natural scale, as the latter are never measured closer than to the nearest $\frac{1}{100}$ inch, I employ the following devices:—The stop *H* arrests the multiplying mechanism at any desired point, after which it moves as a unit, and any further change of length is recorded on natural scale. To act as described, the parallel motion mounted on the bar has *B* two tubes, *R*, sliding on rods, *R*₁, the latter only being fastened to the frame *F*. These

tubes, R, are split, and can be made to grip the rods R_1 with any necessary pressure.

It will be seen that the total maximum resistance to motion between frames F and F_1 is the friction of tubes g and R on rods g_1 and R_1 and friction of pen M. As long as the motion is recorded on a magnified scale this resistance will be only the friction of rods g_1 in tubes g , of pen M, and the resistance of the parallel motion.

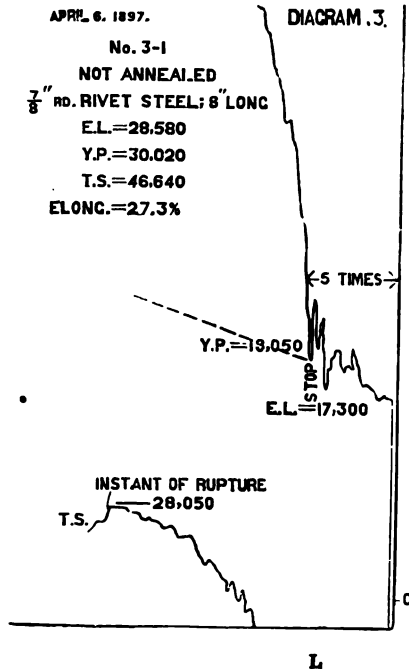
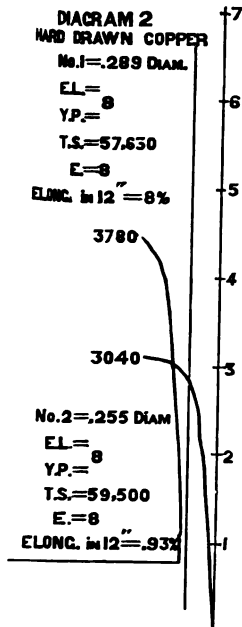
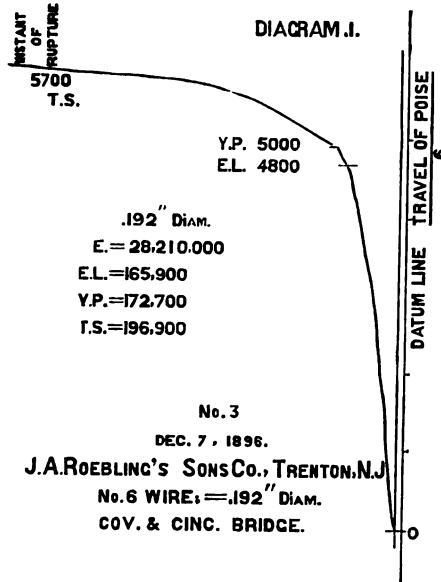
Therefore the total resistance will be minute, and not likely to affect the record in even the slightest manner by slipping of the knife-edges and frames. The paper on the drum must move past the pen m at a rate equal or proportional to the motion of the poise weight on the beam. As loads are large and small according to size and quality of test-piece, the poise must travel more or less to balance it. As it is desirable, however, to record all tests on the same sized diagram, the travel of the poise weight is reduced or increased by a grooved pulley, P, round any groove of which the string C, tied to poise weight, is wrapped; the free end of this string carries a small weight to keep it always at the same tension. On any other groove of the pulley P another string passing around the drum D is wrapped, which is kept at the same tension by a small weight at its free end. By a proper selection of position of the two strings on the various grooves of the pulley, any desired rotation of the drum may be obtained.

Application of Instrument.—A light pulley is secured to the frame of the testing machine, over which the string C passes, the other end being attached to the poise weight, or to any mechanism moving in synchronism with it.

A sheet of paper being mounted on the drum, the frames F and F_1 are opened after the screws S have been so adjusted that the distances between the knife-edges K and K_1 are about $\frac{5}{8}$ inch less than the thickness of the test-piece.

Then the frames are placed around the test-piece, which has been placed in the machine, the frames are closed, pins, p , are inserted, the string C_1 is passed around D, and C round the proper groove on P, while the poise weight is at 0 (zero), and the test may begin.

If it is desired to draw a base line for measurements of elongation, the drum is given one revolution while the pen bears



against the paper; it is not necessary (though it can readily be done) to draw the other axis to the base line, as the motion of the pen is always at right angles to it. If it is desired to mark the scale of loads on the base line, all that is necessary is to revolve the drum by running out the poise to the several load points, and then making a mark for each of them. Once this scale is determined, it will be the same in all work.

In the case of materials with very slight change of length, during the test the automatic stop is not used, and curves like those on Diagrams 1 and 2 are obtained. When ordinary structural material is tested, the stop is used, and a curve like that on Diagram No. 3 is obtained; in this, the elongation is drawn on a multiplied scale from 0 to the point marked "Stop;" beyond this it is drawn to natural scale. The very decided change of direction at the point marked "Stop" cannot be mistaken for anything else.

As all of the instruments hereafter made will have a multiplication of ten times, this point of change of scale will be even more clearly defined than on the card shown.

An investigation of the effect of stretch of the string or wire has demonstrated that it is negligible, and the divisions marked on Diagram 2 will prove this. That it should be so will be clear when it is remembered that the drum revolves with a constant resistance, and that the string itself is always under constant tension, due to the small counterweight tied to the string C.

It will be noted that at the instant of rupture the apparatus can separate into two independent parts, and that the knife-edges permit a certain amount of slip; the combined effect of these two facts obviates any injury to the instrument at the instant of rupture, provided the accidental flying about of the gripping wedges is prevented by blocking them, which is always done by a careful person.

Experience has shown that the instrument can be used rapidly without interfering to any degree with the work of the laboratory, and that the results are perfectly trustworthy.

DISCUSSION.

MR. JOHN A. F. ASPINALL said that, with the ingenuity which distinguished our American cousins, Mr. Henning had produced an instrument which was light, portable, and cheap; but he ventured to doubt whether some of its mechanical details were not capable of improvement, and whether, as they now stood, they would not lead to inaccuracy to a certain extent. Nearly ten years ago he had had an instrument somewhat similar in character, but not portable, made for him by Messrs. Buckton, and fitted to a Wicksteed machine, and it had been in use continuously ever since. But the movements of the pencil were recorded upon a somewhat larger drum, and they were given by the specimens themselves, so as to be in exact proportion to the movement. There was no multiplying arrangement, such as was indicated in Mr. Henning's recorder. It would be observed in the drawing that the motion of the arm to which the pencil was fixed had to be transmitted through four pins, and he thought it was more than likely that even if the instrument was perfectly accurate at first, and perfectly well made, after a time wear would take place, and there would be an inaccuracy due to that motion; an inaccuracy which would be multiplied in the case of the instruments the author intended to make with a multiplication of ten to one.

With regard to the movements of the pencil being so perfectly accurate, it was, he thought, better that those movements should be given by the specimen itself rather than by a mechanical multiplication, which might involve error; and perhaps it would be better for the instrument to be made so as to register the results in the way he had spoken of, afterwards magnifying them by a magnifying glass, so as to get a more accurate reading. There could be little doubt that if such a portable instrument could be produced, it would be of great advantage, and if it could be made so as to be readily attached to the specimen when off the machine, the whole thing could then be carried to the machine and put into it—a second instrument being fitted up for the next specimen while the first was being tested: they would then have

an apparatus which, if constructed sufficiently light and accurately, yet sufficiently strong to stand the rapid work of the testing-room, would give something which many of us would like to have. The Aspinall automatic recorder is illustrated in Plate VII.

RECORDER ON 100 TONS TESTING MACHINE.

Fig. 1 is an end elevation of the apparatus as fixed on the testing machine.

Fig. 2 is a front elevation of the same, showing the connection to a test-piece.

A is a test-piece fixed in the machine; two clips B B¹ are attached to it 8 inches apart; on the bottom clip B¹ rests a steel rod C, with a balance weight at each end; a wire is connected from the centre of this rod to the pencil carriage D, which will cause the pencil to travel equal to the amount of extension of 8 inches of the test-piece (or the strain in 8 inches of length).

The back end of the pencil carriage D is connected by a wire to the tension pulley E.

F is the drum on which the diagram is taken, this drum being fixed on a carriage G, movable on the guide rods H; a wire is connected to the carriage G from the rod J on the top clip B.

L is a handwheel by which the stress is applied to the test-piece A; as the handwheel is revolved the motion is transmitted to the drum F by the gearing and wire.

The movement of the pencil indicates strain, and radial movement of the barrel indicates the amount of stress producing such strain.

Dr. A. C. ELLIOTT (University College, Cardiff) thought that Mr. Henning had been singularly fortunate in securing Mr. Wicksteed to present his paper, because that gave them a claim upon their attention, Mr. Wicksteed being well known as a pioneer worker in the field of automatic recording. As Mr. Henning had remarked, there were many recorders, all more or less perfect; but the question that occurred to one was, what was the primary use of a recorder? Mr. Henning apparently thought that one principal use was the determination of the yield point or the limit of elasticity point. That point was variously circumstanced in different kinds of material. Sometimes it was exceedingly sharp and well marked, and sometimes it was not at all well marked. Sometimes there was an incipient yielding or elastic failure, the straight line recording Hooke's Law running

gently into a curve. On the other hand, the yield-point or elastic limit was sometimes marked by a sudden drop of as much as two tons to the square inch. On a recorder properly so called it was impossible to fix the exact spot where the straight line ended and where it became slightly curved. That was a point to be determined by a delicate extensometer. This brought one to the question whether it was really necessary or desirable to have a portable instrument at all. An instrument of that kind—the recorder kind—should be strong in order to be rigid. If it were not strong, the indications would be of no use whatever. He thought the best way to get a good recorder was to design one to be used *in situ* in relation to the peculiarities of the machine—horizontal, vertical, and so forth.

Then he thought there was another error. He understood that one of the co-ordinates—the stress co-ordinate—was taken from the travel of the poise-weight. If a machine was not in balance, or was badly balanced, the recorder in that case simply recorded errors, the errors of the man working the poise-weight. With some kinds of stuff, particularly nickel steel, which he had been lately working with, when they reached the limit of elasticity, a sort of shiver overtook the material, as distinguished from a mere hook or shake in the curve. The beam dropped dead, and the stress went sharply down, say five tons or so. With a design like Mr. Henning's all that would simply be lost, or, in other words, not recorded, seeing that it was impossible to traverse a jockey-weight by five tons in the twinkling of an eye or the hundredth part of a second. But with a recorder that took the co-ordinate he was speaking of—the stress co-ordinate—from the pressure of the water in the ram cylinder, that great error of omission was not perpetrated. When the stress co-ordinate was obtained independently of the jockey, one could, in the extreme case Mr. Wicksteed had suggested to him on the previous day, run the poise-weight right out to the end of the scale to 100 tons in a 100-ton machine, and take the autographic diagram by merely opening the hydraulic admission valve.

In this case the stress co-ordinates were utterly independent of the floating of the beam. He had had a recorder of the description mentioned by Mr. Henning in use—that was to say, a recorder in which the stress co-ordinate was obtained from

the travel of the jockey-weight—and the diagram produced was nearly useless for the purpose in hand. He had to plot the serviceable diagram from extensometer observations, while the diagram copied from the traverse of the poise-weight was unsatisfactory, and nearly useless. A recorder that took the stress co-ordinate from the traverse of the poise-weight was certainly not better than the Wicksteed recorder, which took that co-ordinate from the pressure in the hydraulic straining cylinder, as already described.

He wished to take that opportunity of saying that he was perfectly convinced that the people who considered the friction of the cup leathers of the ram and its attachments a great thing were wrong, and that the plan he had mentioned was the only one that could be pursued with anything like a hope of getting a correct continuous record. He should not like to condemn a piece of apparatus without having seen it, far less without having tried it. Mr. Henning's recorder might be all very well, and it might turn out well, and it might be portable. He was himself speaking, mainly from experience, of a thing that he knew, and that he had well tried. It certainly was not a machine that could be put in one's pocket, but it was an engineer's tool.

Mr. HADFIELD asked what was the cost of a recorder?

Mr. WICKSTEED said it was about £25.

Mr. HADFIELD said that all who were connected with steel had now to do much more testing than at any former period, and he thought it would be a good plan if Mr. Wicksteed would allow the machine to be exhibited in London, where the members might see it; also if he would allow one to be tested at the Sheffield Technical School. Those in charge of the School were always desirous to keep the students well posted up in any advances that were made, and he should be glad if Mr. Wicksteed could get Mr. Henning to allow them to have one of the recorders there for testing purposes.

He should also be glad to know if the apparatus was suitable for testing high elastic limits. Those who were connected with the manufacture of special steels had to pay special attention to

high elastic limits. For example, the projectile manufacturer depended largely for success upon the elastic limit of his steel, and as to whether he pierced the plate which he had to attack, or the latter smashed his projectile. A difference in the elastic limit of 5 or 10 tons was very important, but it was very difficult to determine in the ordinary way, that was, as regards elastic limits over 30 tons per square inch. He should be glad to know if the apparatus would be suitable for the purpose. His own firm used a small Whitworth machine, which was not usually arranged to take extensions on a longer length than two inches, as they found that served their purposes very well for all practical tests. Could the apparatus be applied to such a small length?

Mr. WICKSTEED said the President had given him an opportunity of taking part in the discussion, not speaking at the moment for the author, but speaking as an ordinary member. He thought the subject was one which should be interesting to the Institute. It had been brought up once before by Mr. Gautier, who had read a paper upon stress strain diagrams.

By means of graphic methods of illustration, many things could be taken in much more rapidly than by columns of figures or mere verbal statements, and he therefore thought that the graphic method was a very great boon. There was more reality in a self-recorded diagram than there was about a statement of results recorded in columns of figures taken down by the experimenter and measured off by him. He did not, however, suppose that there would be very extensive use for autographic diagrams until more attention was paid to two critical points in the behaviour of test-pieces, viz., the yielding-point, and the point at which the maximum strength of the specimen had been reached. At present the large manufacturers merely wished to know the total extension of the piece and the maximum strength; they did not, as a rule, wish to know about the yielding-point.

There was the other critical point, that had not been so much considered as the elastic yielding-point, but the consideration of which would save a great deal of trouble and waste of time in congresses for deciding upon some impossible standard form of test-piece. He said impossible, because he thought it would never come about that the test-pieces from guns, steel tyres,

crossways of an axle, and other items of manufacture, could be reduced to the same proportions as those of an eyebar for a Warren girder bridge or a chain cable, or a long bolt for use in a marine engine. He did not think they could always get those things in the same proportions—that was, a length of say eight diameters, or any other proportion they might choose to fix upon at a congress. He thought it was not practicable to try and establish a form of test-piece which would be the same for all nations, no matter what their unit of measurement was, and which would be of similar proportions in all cases. That brought him to say that he thought it would be entirely unnecessary to reduce test-pieces to similar proportions if only they would separate the general extension, expressed in percentage of length, from the local or breaking elongation, which had no relation to the length, and which was wrongly expressed if expressed in percentage of length. The diagram recorded the local elongation during breaking, that was, after the maximum strength of the piece had been passed; then the piece began to bottle-neck, to draw in, to contract locally and to extend locally. That extension had no relation to the length of the piece, and if a person testing a 2-inch piece credited the 2-inch piece with that local extension, he might report an increased percentage of extension of about 25 per cent. But if he had a 10-inch piece, and he credited that with this constant quantity, this local extension, he only benefited his report to the extent of 5 per cent. Hence all the discrepancies and difficulties of comparison; hence the difficulty of comparing the ductility of a small sample of steel with the ductility of a large piece formed from the same material. It vitiated an exact comparison between the ductility of thick plates and thin plates. If they tested a number of plate strips of the same length but of different thicknesses, the thicker plate would contribute more to the percentage during its local elongation, because the local elongation was a function of the diameter and not of the length. It was perfectly easy to separate the local elongation from the general elongation, because the general elongation always ceased as soon as the strength left off increasing and began to diminish. He had therefore, as a little kindred to the subject, taken the opportunity of setting forth that point as worthy of some attention, and as being a point

that would be attended to when people got accustomed to see a self-recorded diagram in front of them, and to observe the behaviour of the whole thing from start to finish.

MR. PRICE WILLIAMS expressed his regret that the diagrams of Mr. Henning's interesting and valuable paper, which Mr. Wicksteed had so ably supplemented with his remarks upon it, had not been illustrated by diagrams on the walls. He thought it was only due to the author of a paper of that description that such arrangement should have been made. He had not had the opportunity of reading the paper beforehand, and found it impossible to follow the description of the diagrams given in the paper. He believed he was expressing the opinion of a very large number of members present in saying that, and that had the diagrams been so exhibited, and some one employed with a pointer to follow the reader of the paper in his detailed description of the various figures with which it was illustrated, it would have been quite possible to understand them.

He entirely agreed with Mr. Wicksteed as to the great value of graphic illustration in connection with tests of this kind. He was sorry in the remarks he had made to appear in the character of a censor, but he did so purely in the interest of the Institution. He had no doubt the omission of the diagrams on the walls was due to the circumstance that there had not been time to make the necessary preparation for them; the paper, however, was a most valuable one, and he trusted that on future occasions, when papers of this description were read, they would be accompanied by diagrams on the walls. He regretted to find that the author had not mentioned, among the distinguished inventors of testing machines, his old friend Mr. Kirkcaldy, who was an early and distinguished pioneer in these matters. He had reason to believe the first important tests Mr. Kirkcaldy carried out with his beautiful testing machine were those he (Mr. Price Williams) intrusted to him to make in connection with the well-known Chalk Farm and other early Bessemer steel rail tests, the records of which are given in the Proceedings of the Institution of Civil Engineers.

MR. WRIGHTSON said he did not intend to make any remark

on the paper ; indeed he had only entered the room when it was half read. He thought it would be desirable to send such papers round to those who were likely to take an interest in them. This was certainly a most valuable paper and one of extreme interest. In the ordinary way of testing for tensile strain, the clamps were attached at such a distance apart as to leave a distance of 8 inches or 10 inches (according to the varying practice of engineers) clear for observation of changes during the test.

He observed that the instrument now under discussion was attached to points close to the clamps. Therefore all the indications would be average indications. Mr. Wicksteed had drawn attention to the deformation that took place after the stop had taken effect. That, no doubt, was very important, and the value of such a diagram would be very considerable ; but it was still only an average of all the changes which took place. It might be assumed that there was no deformation taking place at the points where the clamps were attached. All the deformation took place between the two clamps, and the amount largely depended upon the proportion between the length and the breadth or thickness of the test-bar. The strains that came upon the bar were not all parallel to its axis, which would be so if the bar were a series of fibres unattached laterally. As elongation took place, these lateral attachments caused strains in almost every direction. The consequence was that they had in a test-bar cross strains which came to their maximum at the centre of the bar, and hence it was here that they always found the most marked reduction of area, if the bar was homogeneous.

It was those cross strains that caused this reduction of area, which, when it came to a certain limit, produced rupture. The instrument did not measure those particular changes, and he thought it would be an extremely difficult problem to endeavour to indicate, by means of any instrument, those local changes, unless very short test-bars were used. As a matter of fact, however, they did get a most valuable indication, when they got the average changes that took place.

Some years ago he made some experiments with regard to the perforation of test-bars, and it might surprise some to know that a very considerable increase in the tensile power was obtained

by the perforation of the bar. The amount of tensile strain that could be brought upon the bar perforated was higher per square inch than when it was not perforated. The reason was that the lateral compression of the sections adjacent to the holes was resisted by the tensile strength exerted laterally through the solid material immediately above and below the holes, having, in fact, the same effect as bringing the clamps down to the holes. On the same principle they found a greater strength if they had a hard bar, because it resisted laterally that contraction of area. He congratulated the author upon the interesting paper he had laid before the members, and also thanked Mr. Wicksteed for the great help he had rendered in the discussion.

Mr. H. C. KING (Swindon) said he would be obliged, and probably many others would be enlightened, if the author would point out where the magnification of the diagram ceased, and where the normal scale began. This point might possibly be determined by a second datum line marked before the test commenced, and need be so determined before the instrument could be regarded as an impartial recorder, and its results pass unchallenged. Experience might have shown that the instrument could be used in a laboratory without interfering with the work done there, but it certainly would be of doubtful utility in a commercial testing house, the amount of testing to be done to-day leaving no time margin for setting up such an instrument, even were its records as absolutely correct as the author claimed.

It was not easy to estimate the value of such an instrument by the examination of a sketch, as much might be done to give a long life to joints and knife-edges by hardening; but, as had already been pointed out during discussion, the chances of error were considerable, owing to the many joints and pins involved in its construction. Setting aside that objection, the greater one remained that, taking as it did its load ordinate from the travel of the poise or jockey, the accuracy of that record was at all stages entirely dependent upon the skill or care with which the operator kept the beam floating until the maximum strain was reached, then, as was well known, if the metal was other than brittle, local reduction of area and corresponding elongation would rapidly take place, the test-piece would no

longer support the maximum load, and the beam would rest upon its lower stop until ultimate fracture; but with such an instrument as the one under consideration, the maximum load would be recorded as the load sustained when the test-piece fractured. Engineers and manufacturers recorded the maximum load sustained and the final elongation, these figures forming a convenient basis of comparison for similar metals. So often had these figures been produced side by side that some had regarded these characteristics as associated and observable at the same time in the piece tested. A diagram which could not record the marked decrease in the load sustained when a ductile test-piece began to strangle, not only added nothing to the knowledge of the material, but would appear to give experimental support to a fallacy already widespread.

Upon examining the diagrams produced with the paper, one could only regret the absence of explanatory notes. No. 3, which broke at 20·8 tons per square inch, possibly was a defective sample, as such very mild steel would not usually sustain an increasing load until the instant of fracture, as shown; nor should one expect to find 20·8 tons per square inch associated with only 27·3 per cent. in 8 inches. 24 tons per square inch being commonly found to give 30 to 34 per cent. elongation, and that measured over ten inches, the operator may have failed to balance the straining load, and the test-piece, if measured, might possibly have been found to have stretched more than recorded, such defect being not unknown in existing drum recorders.

Could a portable recorder be devised possessing the power of divination outlined by the author, *i.e.*, indicating at a glance how the material had been treated, judiciously or otherwise, during manufacture, it would be a very useful tool. The author's conception was very comprehensive, his specification very complete, but whether this ideal instrument was materialised in the very ingenious mechanism described was, in his opinion, more than doubtful.

Professor R. H. SMITH agreed with what Mr. Wicksteed had said with regard to the desirability of having autographic diagrams. He thought that Mr. Wicksteed had done them great service when he explained, a few years back, the desirability of

leaving out of account altogether the local stretching within 1 inch or $1\frac{1}{4}$ inch—never more than $1\frac{1}{4}$ inch long in ordinary commercial test-pieces. That point would bear repetition a good deal, and it ought to be strongly impressed upon the memories of all who had to deal with testing material. As Mr. Wicksteed had said, the local stretching began only when the curve approached its maximum height, and he should like to mention that really the curve in this region and beyond the maximum height could be varied greatly in shape by manipulating the machine more rapidly or more slowly. No doubt the local stretching was interesting from a physical point of view, and if it were treated in a very scientific and complete manner, it might show a good deal with regard to the quality of the material; but as a commercial test he did not think it was of any value at all. It could be made great or small, and the possible variations were not taken account of in the ordinary consideration of that point.

He sympathised a good deal with the object of the instrument explained in the paper, and the desire to make it portable, although he thought that every high-class machine of any magnitude ought to have its own automatic recorder *in situ*. It would have been a great advantage to have had the instrument before them. It was impossible to criticise an instrument like that as to its mechanical qualities merely from a diagram. Looking merely at the diagram, he should suspect, having used many different devices for the same purpose, that there were a great many points about its construction that were open to criticism. As had been already hinted, he thought there were far too many joints about the apparatus—that was, there were far too many places where slackness due to wear might come in and vitiate the results. The sliding tubes would allow, after a little wear, some tilt of the drum, and that was extremely important with regard to the accuracy of the diagram.

Mr. WICKSTEED, in reply, said he was sure his friend Mr. Henning would be much gratified by the way in which his paper had been listened to, and with the discussion it had elicited. He would be specially gratified at Mr. Aspinall taking hold of the idea of putting a portable recording instrument on to each speci-

men outside the machine, so that it should be put into the machine and make its record, and then be taken away again and another one come on. He thought that idea would delight Mr. Henning very much. Dr. Elliott had run the instrument down in comparing it with a really autographic recorder. The instrument described in the paper was a mechanical recorder—it was not strictly an autographic one. It did not do its own work independently of the manipulation of the machine. He did not, however, go so far as Dr. Elliott, who had mentioned the rapidity with which changes took place at certain critical points, as doing away with the utility of a mechanical recorder. The benefit of a mechanical recorder was that at the same instant at which the test-piece stretched in an unforeseen way at the yield-point the record was made of the position of the poise: whereas, if they measured with a pair of compasses, with the legs held into the datum points of the specimen, and a yield suddenly took place, the poise was then away. If they called out to the man reading the position of the poise, "Now the piece has yielded," they had lost the record. But the pencil that drew the curve, which was governed by the extension of the specimen, and also the movement of the poise, recorded the two things simultaneously.

There were some complicated tests that they might have to make with riveted joints. Suppose they had eight rivets in a joint with double butt straps in which it happened that there were twenty-four places at which the plates might slip upon the rivets. Each rivet passed through three plates, so that there were twenty-four places where slip might occur. If they wanted to find the best riveted joint, not in regard to ultimate strength, but in regard to the first point at which the plates shifted past each other, which was really the point at which leak or deformation would begin, it would be found easy to do it if they had a mechanical recorder, which would tell where every little slip took place. The first might be so insignificant that it meant nothing but coming home against some slack rivet till all the rivets came to act as pins. Still this little slip showed them where the tightening effect of the rivet heads to bring the faces of the plates together failed to carry more load. It told them all about it; but it was different when trying to do it with one man at the steelyard and another man at the trammel or compasses.

The man at the trammel said "Slip;" the man at the steelyard said "Sixteen tons;"—but he could not know exactly; he had really been all the time travelling the weight along the steelyard, and probably when he read the scale had already travelled the weight beyond the point at which the slip actually took place.

It had been remarked by Mr. Price Williams that they ought to have had a cartoon. If he (Mr. Wicksteed) were trying to answer Mr. Wrightson's speech, he should want a blackboard as well as a cartoon. He thought he had better not go into the matter, because it would take far too long. Mr. Price Williams had stuck up for his old friend Mr. Kirkcaldy, but Mr. Kirkcaldy had all his life resisted the idea of autographic diagrams. All his diagrams were plotted. They were first taken by measurement and observation, and afterwards plotted in the form of curves. They were never drawn by the test-piece itself. Mr. King had asked what was the limit of magnification. There was a little hook in the instrument, and it could be set so that as soon as the first $\frac{1}{8}$ inch of extension had been passed the whole frame travelled as one unit, and made the rest of the extension the natural size. He should have liked to say something with regard to the observations of Professor Smith, but the time allotted to him had expired.

MR. PRICE WILLIAMS asked whether the instrument would be exhibited.

MR. WICKSTEED said he would write to Mr. Henning and ask him to send an instrument to be on the table at the next meeting of the Institute in London.

MR. HENNING, in reply to the discussion on his paper, sent the following communication:—It is to be regretted that the instrument could not be on exhibition during the meeting, as this would have modified many of the statements made, which are due mainly to lack of familiarity with it, and failure to read the paper carefully. Messrs. Aspinall, King, and Smith attack the accuracy of the parallel link motion, which is in universal use on indicators by steam engineers, and is known to give uniformly accurate results and general satisfaction. Many thou-

sands of these are in daily use all the world over, and are found wanting, even at the high speeds at which they are operated when testing steam-engines. The same device, however, used for very slow motions, is at once attacked as "inaccurate and subject to wear," the critics probably failing to note that the motion is always in one direction throughout every test. The suggestion made that extensions be recorded on actual scale, and then read by a microscope, unless made with a diamond, has been studied and tried and found wanting; the record made is much less than the thickness of any line which can possibly be made by pen or pencil. Moreover, the use of a microscope is very expensive, and takes very much time, hence the primary object of a record "visibility" is lost. It might answer in a college laboratory where time is no object, but is an impossibility in a shop or mill. In obtaining records of practical utility in routine work, it is essential that they be at once and at all times visible, and this is of far greater value than absolute scientific accuracy. Every person familiar with scientific work knows that errors exist in every case, and cannot be avoided, and that it is necessary and essential to establish the limit or amount of error.

Evidently Dr. Elliott has not read the paper, otherwise he would not assume what he asserts, that I consider it to be the primary use of a recorder, which I have explained very fully and clearly.

He assumes that a properly constructed recorder will "not fix the exact spot where the straight line ended and where it became slightly curved. That was to be determined by a delicate extensometer." If a recorder for this object be constructed it will do its work, and this has been done. No one assumes to measure elastic changes of length with a foot-rule, but "indications" are radically different from measurements. Distinguishing colours is very easy, while measuring their wavelengths is very difficult.

As I disclaim scientific accuracy for my recorder, any criticism of it as an instrument of precision is invidious and out of place.

It is clearly pointed out by Dr. Elliott that "if a machine was not in balance, or was badly balanced, the recorder in that case simply recorded errors, the errors of the man working the

1. The first part of the document is a list of names and addresses of the members of the committee.

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poise weight." He therefore criticises the recorder for doing so, and totally fails to understand the primary function of a recorder, namely, to record tests as they are made, so as to show not only the properties of materials, but also the character of the machine as well as of its operator, in order to avoid or correct both of the latter, without introducing new errors. The very foundations for the necessity of a recorder are the uncertainty of the machine and the man operating it; every machine and man being defective, it becomes imperative to define or record the degree, and then obviate the error in future.

It is also assumed by Dr. Elliott that the drum is actuated by the poise weight, while I say that it should be actuated by "any part of the machine moving in proportion to the loads applied." Now, in the hands of a competent operator (the only one who should be charged with making tests), the poise moves forwards and backwards strictly in proportion to the loads applied. It may therefore legitimately serve to turn the drum, and it would be unreasonable to adopt any other mode of procedure.

As Dr. Elliott seeks this opportunity of emphasising his opinion that the belief that friction due to cup leathers in hydraulic machines was erroneous, I wish to record it as a fact that in large testing machines I have found the friction to amount to from 6 to 16 per cent. of the loads transmitted. A recent investigation of one of the largest testing machines in existence proved the presence of friction equal to 15 per cent. of the loads applied.

In answer to Mr. Hadfield's question relating to high elastic limits, I wish to call his attention to Diagram 1, which gives the curve of steel having a tensile strength of 196,900 lbs., and an elastic limit of 165,900 lbs. These can be and are determined with equal facilities to low limits; but as the materials usually showing these qualities are commonly tested in 2-inch lengths, I have constructed a similar recorder applicable to 2-inch test pieces, and multiplying 100 times, as elastic changes of such short pieces could not otherwise be readily recorded.

In answering Mr. Wrightson's criticism, I wish to point out that the recorder is not attached, so that the diagrams show the effect of shoulders, gripping wedges, or similar points. The attaching knife-edges are sufficiently distant from disturbing influences,

such as clamps, &c., and permit constant ocular inspection of the material under test. The changes occurring at and after stricture commences are purely local, and during this period the other parts of the material remain practically unchanged; hence the latter part of the diagrams after the maximum load-point shows precisely what is transpiring during the period of local contraction just as well as though a short piece had been tested. Mr. H. C. King desires to know where the magnification of the diagram ceased. Diagrams 1 and 2 were made without use of stop, and No. 3 alone shows the point where magnification ceases, and is indicated by the word "stop." I would again emphasise the fact that the instrument requires so little time to be applied to the test-piece, that it is not only a laboratory, but also a practical instrument for routine or commercial testing, wherever the latter is done with any degree of reasonable neatness or accuracy. I must repeat to Mr. King that one of the important objects of a recorder is to serve as a controller of the actions of the person operating the testing machine, and if it shows all the shortcomings of man and machine, one of its most essential missions is fulfilled. I also wish to point out to Mr. King that in a properly made test, the beam must float level up to the very instant of rupture, and never rest against either top or bottom stop; if the latter occurs, the test has been carelessly made. The diagrams show that the instrument records all loads after the maximum carried up to the instant of rupture. Diagram No. 3 is correct, because the test-piece broke suddenly. The elongation of the test-piece by measurement after rupture also agreed with that recorded by the instrument.

The PRESIDENT said he had much pleasure in proposing a hearty vote of thanks to Mr. Henning for his able paper, in which might be included the thanks of the members to Mr. Wicksteed. As their time was drawing to a close, he was afraid that it would be necessary to take the paper on "Spectrographic Analysis of Iron Ores," by Professor Hartley and Mr. Ramage, as read, and also Mr. Louis's paper on "The Iron Industry of Hungary." He would, however, ask the members to pass a hearty vote of thanks to those gentlemen for their contributions.

The PRESIDENT proposed votes of thanks to the Mayor of Cardiff, to the President and Council of the South Wales Institution of Engineers, to the Chairman (Sir William Thomas Lewis, Bart.), the Hon. Treasurer (Mr. William Williams), the Hon. Secretary (Mr. T. Hurry Riches), and the members of the local Reception Committee, to the Taff Vale, the Rhymney, the Barry, and the Great Western Railway Companies, and to the proprietors and managers of the various docks and works of the district which the members were about to visit or had visited. He also proposed a special vote of thanks to those who had promised to extend their hospitality to the members during the next few days, the Marquis of Bute, Lord Windsor, Lord Wimborne, Messrs. Crawshay Brothers, the Monmouthshire and South Wales Coal Owners' Association, the Cardiff Chamber of Commerce, the Taff Vale Railway Company, the Mayor and Corporation of Newport, and the Chairman and Board of the Newport Harbour Commissioners, and to the Barry Dock and Railway Company.

Mr. W. WHITWELL, Hon. Treasurer, had much pleasure in seconding the proposition, and as gratitude is somewhere described as a sense of favours to be received, he did so with all the more pleasure in anticipation of what was in store for them. Notwithstanding all the successful meetings of the Institute which he had had the pleasure of attending, and they had been legion, he never remembered one where the organisation had been more admirable than that of the meeting at Cardiff, where Providence had absolutely smiled upon them by the lovely weather, and where the other attractions had been so great. They had had wonderful receptions on the Continent, and a still more wonderful reception in America; but coming back to the great centre, the commencement of the iron and steel trades of the country, they felt increasing wonderment and gratification at what they had seen, and what they were expecting to see. He did not think it was possible for them to gauge the measure of thanks due to their friends, but he was sure that to Mr. Riches they were deeply indebted for a great deal of the real work of organisation. There was no success in any work without organisation of a very exact and detailed kind. They could not

gauge that work, and therefore could not measure their thanks to Mr. Riches, but their gratitude was certainly very great, and their anticipations for the future were still greater. On behalf of the members, he had very much pleasure in seconding what had fallen in such a modest way from the President. He did not think they had ever had a President more popular than Mr. Martin, and that, he thought, must in some degree be the reason why they were present in such great numbers—500 members, and several hundred ladies in addition. On their behalf, on behalf of the Institute generally, including absentees, he seconded the motion that their grateful thanks be recorded for what had been done, and what was about to be done for their benefit.

The motion was unanimously adopted.

Mr. HEYWOOD, in acknowledging the votes of thanks, said that, in the absence of Sir William Lewis, he had been requested, on behalf of the Reception Committee, to say how much pleasure it gave them to find that their efforts to make the meeting a success had been appreciated. From the first, when it was suggested by the Council to hold this meeting in Cardiff, Sir William Lewis had been most anxious that it should be a record one, and he had certainly worked very hard to make it so. His first suggestion, that Mr. Riches should be the Honorary Secretary, showed how valuable had been his advice throughout. Mr. Whitwell had anticipated what he had intended to say with reference to the labours of Mr. Riches, who, as the Reception Committee well knew, had done all the detailed work, indeed had worked not only throughout the day, but during most of the night. As he might have no other opportunity, he wished, on behalf of the Reception Committee, to thank Mr. Riches for his very valuable services. The measure of their indebtedness to him was the measure of the appreciation of the members of the Institute.

Mr. T. HURRY RICHES said that Mr. Heywood had been very kindly complimentary to him. The best thanks that any Secretary who had his heart in his work could receive was to know or to believe that those whom he had had the pleasure of working

for were satisfied. He could only say that it had been to him a very great pleasure to be of any service to the Iron and Steel Institute. There were many members of that Institute who were old friends of his own, and, if only on that account, it was a special pleasure to him to be of service to them. If the members at the end of the week went away satisfied, he should feel more than rewarded.

Mr. WINDSOR RICHARDS, Past-President, said he was sure the members would all agree that the President had conducted the business of the meeting in a manner that was eminently satisfactory. He begged to propose a hearty vote of thanks to him for his able conduct in the chair.

Mr. ARTHUR KEEN, Vice-President, had much pleasure in seconding the resolution. They were, he said, deeply indebted to the President for the very able way in which he had conducted the proceedings of the meeting.

The motion was carried by acclamation.

The PRESIDENT said he was much obliged to the members for the way in which they had received the resolution. He felt that he should be sailing under false colours if he did not state his belief that the success of the meeting (apart from the proceedings in the room in which they were then assembled) was entirely due to Sir William Lewis, Mr. Riches, and the Local Reception Committee.

A SPECTROGRAPHIC ANALYSIS OF IRON ORES AND ASSOCIATED MINERALS.

By W. N. HARTLEY, F.R.S., AND HUGH RAMAGE, A.R.C.Sc.I., F.I.C., F.C.S.,
ROYAL COLLEGE OF SCIENCE, DUBLIN.

IN the examination of the spectra of the flame from the converter used in the basic Bessemer process, lines and bands were photographed which were proved to be absent from the flame from the acid process, and yet they could not be attributed to the basic materials of the charge. Some of these lines were characteristic of the rarer metals. They were likewise found in metallic iron from the blast-furnace, in rail-steel, and in aluminium, reduced from alumina obtained from Irish bauxite; in addition, several elements not usually considered as constituents of iron and steel, or of aluminium, were also present, as, for instance, lead, silver, copper, gallium, and chromium.

We were desirous of studying the Bessemer flame in works other than those already visited, but as circumstances have prevented our having the opportunity of carrying on further investigations in this direction, such work for a time has been suspended. Finally, on consideration of the whole subject, it seemed possible to attack the question of the origin of these lines in the spectra from another point of view. Thus, having already proved the volatility of a large number of elements and their compounds in (*a*) the oxyhydrogen flame, and (*b*) the carbonic oxide flame, it seemed a matter of considerable interest to examine a large collection of iron ores for volatile constituents of a metallic nature. By so doing it is easy to ascertain the elements which might be found in the metal smelted therefrom, those to be looked for in the flame from the converter, and those which might be expected to pass into the steel as the final product of such ores.

Having regard to the fact that some of the elements known to present are not volatile at the temperatures employed, such as

vanadium, titanium, and silicon, and that others have but little emissive power, such as zinc and aluminium, it is necessary to draw a distinction between the two categories; but, without entering into detail with respect to each element, it is proposed to state simply those which have been found in the ores and minerals examined by means of their photographed spectra, for these are the substances which would appear in the Bessemer flame.

The details of the examination of ninety-one specimens are contained in Tables I. to VI. inclusive. The relative proportions of the elements present in small quantity are indicated, but not the actual quantities. It would, however, be a simple matter, in any cases of particular interest, to render these results quantitative by photographing comparison spectra obtained from weighed quantities of pure materials, by counting the number and measuring the intensities of the lines in both cases, as in every instance weighed quantities of ore were employed.

In Tables VII. to IX. inclusive, there is a statement of the elements detected in such minerals as may be mixed with a charge of ore, or may adventitiously occur therein.

The minerals referred to are pyrites and such as contain chiefly alumina and manganese.

Mention must not be omitted of a paper we communicated to the Chemical Society on "The Wide Dissemination of some of the Rarer Elements, and their Mode of Association in Common Ores and Minerals."* The present communication deals with the same collection of ores, but it treats the examination of them in a totally different manner, the results being relatively quantitative and carefully tabulated, so that the evidence afforded may readily be comprehended. The method of examination was similar to that employed in observing the volatile constituents of the Bessemer flame, weighed quantities of the ores or minerals being simply burnt in the oxyhydrogen flame, and the spectrum photographed with the same instrument.†

In many cases the same ores, before and after calcination, were examined, which is obviously an advantage, as it is the calcined material which is smelted. Half a gramme of each substance was generally taken, and as, in the state of powder, they were

* *Transactions*, vol. lxi. p. 533.

† *Journal of the Iron and Steel Institute*, vol. xlviii. p. 95.

difficult to manipulate in an ordinary support of kyanite, the powders were wrapped up in ashless filter-papers, and burnt in the oxyhydrogen flame. Blank experiments were, of course, made with the same paper to ascertain that no impurities were thereby introduced. The spectra were measured, and wave-lengths of the lines determined; when this has once been accomplished, spectra photographed for comparison yield satisfactory results for the purpose of identifying the lines of the elements which are present.

In the paper we have referred to, we sought information concerning the geological distribution of the rarer elements, and of facts helping to elucidate the origin of ore deposits.

The formation of minerals, and of lodes and beds of ore, has been dealt with by Gustave Bischof,* by Irving and Van Hise, more recently by Professor Franz Posepny† and by S. F. Emmons.‡ In the prosecution of such inquiries we believe that the method pursued by us will prove of considerable value, as it has enabled us to arrive at important generalisations.

*Explanation of the Symbols, Numbers, and Abbreviations used
in the following Tables.*

In column I. the specimen's number is stated.

Column II. contains the name of the ore or mineral, and its locality. Specimens marked (a) are from the Metallurgical Collection of the Royal College of Science; (b) from the Science and Art Museum; and (c) from the minerals used for analytical practice in the Chemical Laboratory of the Royal College of Science, Dublin; (d) minerals purchased recently; (e) from Professor J. P. O'Reilly's Collection; (f) from the Mineralogical Collection of the Royal College of Science, Dublin.

The symbols following the name of a specimen indicate the elements present in the sample. When plain type is used the lines of the element are very strong in the spectrum of the

* "Chemical Geology."

† "The Genesis of Ore Deposits," *Transactions of the American Institute of Mining Engineers*, special edition.

‡ "Geological Distribution of the Useful Metals in the United States," *Transactions of the American Institute of Mining Engineers*, vol. xxii. p. 53, 1894. "A Treatise on Ore Deposits," Phillips and Louis, 1896.

specimen. When printed in italics, it indicates that the lines are weak, and traces only of the metal are present.

An index figure after the symbol—thus, Ni 2—indicates the strength of the lines in the spectrum when the element is present in small quantity. When the line or lines are sufficiently distinct to show that the quantity of the element is in excess of mere traces, the figure 1 is used; clear and distinct lines are indicated by 2; stronger lines are represented by numerals up to 9, which figure represents the intensity of the strongest lines seen in the spectrum of that mineral which is at present known to be the richest source of the element in question—thus, Ga 5 and Ga 9. The Bensburg and Piérrefitte blends are richest in gallium, while that of Freiberg is richest in indium. Any ores as rich as these minerals, as determined by comparison with standard photographs, would be represented by Ga 9 or In 9.

The intensity of the lines of silver, copper, and thallium, lead, chromium, nickel, &c., are indicated by a similar scale.

TABLE I.—*The Composition of Iron Ores, chiefly Clay Ironstones, Spatheose Ores, and Black Band.*

I.	II.	Sodium.	Potassium.	Rubidium.	Silver.	Copper.	Calcium.	Gallium.	Indium.	Thallium.	Iron.	Nickel.	Manganese.	Chromium.	Lead.
1 {	Calined Cleveland ore, from the North-Eastern	Na	K	?	Ag 1	Cu 2	Ca	Ga 3	...	...	Fe	...	Mn	Cr 3	Pb 3
2 {	Steel Co.'s Works, Middlesbrough	Na	K	...	Ag 1	Cu 1	Ca	Ga 1	...	...	Fe	Ni 1	Mn	Cr 1	Pb 2
3 {	Cleveland ironstone, Middlesbrough (a)	Na	K	...	Ag 1	Cu 2	Ca	Ga 2	...	...	Fe	...	Mn	Cr 3	Pb 2
4 {	Clay ironstone, Yorkshire (a)	Na	K	Rb	Ag 2	Cu 2	Ca	Ga 2	...	...	Fe	...	Mn	Cr 1	Pb 1
5 {	Grosmont, Whitby, Yorkshire (a)	Na	K	?	Ag 2	Cu 3	Ca	Ga 1	...	...	Fe	...	Mn	...	...
6 {	Grosmont, Whitby (a)	Na	K	?	Ag 2	Cu 1	Ca	Ga 1	...	...	Fe	Ni 1	Mn	Cr 1	Pb 1
7 {	Hedley Collieries, Northumberland (a)	Na	K	?	Ag 2	Cu 1	Ca	Ga 1	...	...	Fe	...	Mn	...	...
8 {	Hedley Collieries, calcined (a)	Na	K	?	Ag 1	Cu 1	Ca	Ga 2	...	...	Fe	...	Mn	...	...
9 {	Nodules (a)	Na	K	?	Ag 2	Cu 2	Ca	...	...	...	Fe	...	Mn	...	...
10 {	Merthyr Tydvil, South Wales (a)	Na	K	?	Ag 2	...	Ca	...	...	...	Fe	...	Mn	...	...
11 {	balls, calcined (a)	Na	K	?	Ag 1	Cu 3	Ca	Ga 1	...	...	Fe	...	Mn	...	Pb 2
12 {	Castlecomer, Co. Kilkenny (a)	Na	K	?	...	Cu 2	Ca	Ga 2	...	...	Fe	Ni 2	Mn	Cr 1	Pb 1
13 {	Northamptonshire (a)	Na	K	?	Ag 1	Cu 2	Ca	Ga 1	...	...	Fe	...	Mn	Cr 2	Pb 2
14 {	Iron spar, Brendon Hill Iron Mines, Somersetshire (a)	Na	K	?	Ag 2	Cu 1	Ca	...	...	...	Fe	...	Mn	...	...
15 {	Clay ironstone, Northamptonshire ore, calcined (a)	Na	K	?	Ag 1	Cu 1	Ca	...	...	...	Fe	Ni 1	Mn	...	Pb 2
16 {	Calined ironstone, Normandy Mine, Yorkshire (a)	Na	K	Rb	...	Cu 1	Ca	Ga 1	...	...	Fe	Ni 1	Mn	Cr 2	Pb 1
17 {	Bassy ironstone, Longton, Staffordshire (a)	Na	K	?	Ag 1	Cu 1	Ca	...	...	...	Fe	Ni 1	Mn	...	Pb 1
18 {	Bassy ironstone, Longton, calcined (a)	Na	K	?	Ag 1	Cu 1	Ca	...	...	...	Fe	...	Mn	...	...
19 {	Old Man ironstone, Derbyshire (a)	Na	K	?	Ag 1	Cu 2	Ca	...	...	...	Fe	...	Mn	...	...
20 {	Gubbin ironstone (a)	Na	K	?	Ag 1	Cu 2	Ca	...	...	...	Fe	Ni 1	Mn	...	Pb 3
21 {	" " calcined (a)	Na	K	Rb	Ag 1	Cu 2	Ca	...	...	...	Fe	...	Mn	...	Pb 1
22 {	Ball ironstone (a)	Na	K	?	Ag 1	Cu 2	Ca	...	...	...	Fe	...	Mn	...	Pb 1
23 {	" " calcined (a)	Na	K	?	Ag 2	Cu 3	Ca	...	...	...	Fe	...	Mn	...	Pb 1
24 {	Diamond ironstone, calcined (a)	Na	K	?	Ag 1	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 1
25 {	White ironstone (a)	Na	K	?	Ag 1	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 3
26 {	" " calcined (a)	Na	K	?	Ag 1	Cu 2	Ca	Ga 2	...	...	Fe	Ni 1	Mn	...	Pb 2
27 {	Blue Flats ironstone (a)	Na	K	?	Ag 1	Cu 2	Ca	Ga 1	...	...	Fe	...	Mn	...	Pb 1

TABLE II.—*Brown Hematites.*

I.	II.	Sodium.	Potassium.	Rubidium.	Silver.	Copper.	Calcium.	Gallium.	Indium.	Thallium.	Iron.	Nickel.	Manganese.	Chromium.	Lead.
52	Pistolite hematite, Louveigneur (a) . . .	Na	K	Rb	Ag 2	Cu 2	Ca	Ga 2	..	..	Fe	Ni 1	Mn	Cr 2	Pb 1
53	Brown hematite, Aryleur, near Liège (a) . . .	Na	K	?	Ag 1	Cu 3	Ca	..	..	..	Fe	..	Mn	..	Pb 2
54	" " St. Maur, Meuse (a) . . .	Na	K	?	Ag 2	Cu 3	Ca	Ga 1	..	..	Fe	Ni 3	Mn	Cr 1	Pb 1
55	" " Graux, S. W. of Namur (a) . . .	Na	K	?	Ag 1	Cu 2	Ca	..	..	..	Fe	Ni 3	Mn	Cr 1	Pb 9
56	" " Werbomont (a) . . .	Na	K	?	..	Cu 2	Ca	..	..	..	Fe	Ni 1	Mn	..	..
57	" " Cornwall (a) . . .	Na	K	?	Ag 1	Cu 1	Ca	..	In 1	..	Fe	Ni 1	Mn	..	Pb 1

TABLE III.—*Limonites.*

58	Limouite, locality unknown (a) . . .	Na	K	?	Ag 1	Cu 4	Ca	..	..	..	Fe	Ni 4	Mn	Cr 2	Pb 1
59	" " Langenstriedgés, Saxony (d) . . .	Na	K	?	Ag 3	Cu 4	Ca	..	..	..	Fe	Ni 2	Mn	..	Pb 4
60	" " Lercoul, Arriège, France (d) . . .	Na	K	?	Ag 1	..	Ca	..	..	..	Fe	..	Mn	..	..
61	" " Fleetwood, Pennsylvania, U.S.A. (d) . . .	Na	K	?	Ag 1	..	Ca	Ga 1	..	..	Fe	..	Mn	..	Pb 1
62	Bog iron ore, Ippendorf, Rhine (d) . . .	Na	K	?	Ag 1	Cu 1	..	..	..	..	Fe	Ni 1	Mn	..	Pb 1

TABLE IV.—*Red Hematites.*

I.	II.	Sodium.	Potassium.	Rubidium.	Silver.	Copper.	Calcium.	Gallium.	Indium.	Thallium.	Iron.	Nickel.	Manganese.	Chromium.	Lead.
63	Hematite, Osnaburg, Germany (b)	Na	K	...	Ag 1	Cu 2	Ca	...	In 1	...	Fe	Ni 1	Mn	Cr 2	Pb 4
64	" Haycock Mine, Ontario, Canada (b)	Na	K	...	...	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 1
65	" Eavestock, Saxony (b)	Na	K	...	Ag 1	Cu 1	Ca	...	In 1	...	Fe	...	Mn	...	Pb 1
66	" Altenburg, Saxony (b)	Na	K	...	Ag 1	Cu 5	Ca	Ga 1	...	Tl 3	Fe	...	Mn	...	Pb 3
67	" Schwarzenberg (b)	Na	K	Rb 2	Ag 1	Cu 1	Ca	Ga 1	In 2	...	Fe	Ni 1	Mn	...	Pb 4
68	" Ergebirge (b)	Na	K	...	...	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 2
69	" Schneeberg, Saxony (b)	Na	K	...	...	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 1
70	" Elba (b)	Na	K	...	...	Cu 1	Ca	...	...	...	Fe	...	Mn	...	...
71	" Cleator Moor, Cumberland (d)	Na	K	...	Ag 1	Cu 1	...	...	...	...	Fe	...	...	...	...
72	" Antwerp, New York (d)	Na	K	...	Ag 3	Cu 1	...	...	...	...	Fe	...	...	...	...
73	" Iron Glance, Elba (d)	Na	K	...	Ag 2	Cu 1	...	...	...	...	Fe	...	...	...	...
74	" " Canada (d)	Na	K	...	Ag 2	Cu 1	...	...	...	...	Fe	...	...	...	...
75	" " Norberg, Sweden (d)	Na	K	...	Ag 1	Cu 2	Ca	...	...	...	Fe	...	Mn	...	Pb 1
76	" Iron ore, Styria (b)	Na	K	...	Ag 1	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 2
77	" Hematite, Llantrisant, Wales (a)	Na	K	?	Ag 1	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 1
78	" " Specular iron ore (a)	Na	K	...	...	Cu 1	Ca	Ga 1	...	...	Fe	...	Mn	...	Pb 1
79	" " " Darlingsberg, Sweden (a)	Na	K	?	Ag	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 1
	" " " Mossaberg, Sweden (a)	Na	K	...	...	Cu 1	Ca	...	...	...	Fe	...	Mn	...	...

TABLE V.—*Magnetites.*

		Sodium.	Potassium.	Rubidium.	Silver.	Copper.	Calcium.	Gallium.	Indium.	Thallium.	Iron.	Nickel.	Manganese.	Chromium.	Lead.
80	Magnetite, Moria Mine, Essex Co., New York (d)	Na	K	?	Ag 1	Cu 1	Ca	Ga 1	...	...	Fe	...	Mn	...	Pb
81	" Ozarka Mountains, Arkansas (d)	Na	K	...	Ag 1	Cu 1	Ca	Ga 2	...	...	Fe	...	Mn	...	Pb
82	" Opdal Skage, Namias, Norway (d)	Na	K	?	Ag 1	Cu 2	Ca	Ga 1	...	...	Fe	...	Mn	...	Pb
83	" Magnetite iron ore, Darlingsberg, Sweden (a)	Na	K	?	Ag 2	Cu 1	Ca	Ga 2	...	...	Fe	...	Mn	...	Pb
84	" " Bisping, Sweden (a)	Na	K	?	Ag 1	Cu 1	Ca	Ga 2	...	...	Fe	...	Mn	...	Pb
85	" " Dannemora, Sweden (a)	Na	K	?	Ag 1	Cu 1	Ca	Ga 1	In 2	...	Fe	...	Mn	...	Pb
86	" " Magnetic iron sand, washed from sand in Bray Strand, Co. Dublin	Na	K	...	Ag 1	Cu 1	Ca	Ga 1	...	...	Fe	...	Mn	...	Pb

TABLE VIII.—Various Manganese Ores and Minerals.

I.	II.	Sodium.	Potassium.	Rubidium.	Silver.	Copper.	Calcium.	Gallium.	Indium.	Thallium.	Iron.	Nickel.	Manganese.	Chromium.	Lead.
109	Spanish ore, 15 % Mn., used at Middlesbrough	Na	K	Rb 1	Ag 2	Cu 1	Ca	...	In 1	...	Fe	Ni 3	Mn	...	Pb 8
110	Pyrolusite, Geisen, Saxony (d)	Na	K	Rb 2	Ag 1	Cu 3	Ca	...	...	Tl 3	Fe	Ni 3	Mn	...	...
111	" Ilmenau, Thuringia (d)	Na	K	Rb 2	Ag 1	Cu 3	Ca	Ga 1	...	...	Fe	Ni 1	Mn	...	...
112	Pailomelane, near Dolgelly, N. Wales (d)	Na	K	Rb 3	Ag 1	Cu 4	Ca	Ga 3	...	...	Fe	Ni 4	Mn	...	...
113	" Lores, Spain (d)	Na	K	Rb 2	Ag 1	Cu 2	Ca	...	...	...	Fe	Ni 1	Mn	...	...
114	" Siegen, Westphalia (d)	Na	K	Rb 2	Ag 1	Cu 1	Ca	...	...	...	Fe	Ni 1	Mn	...	...
115	Rhodonite, near Dolgelly, N. Wales (d)	Na	K	Rb 2	Ag 1	Cu 1	Ca	...	...	...	Fe	Ni 1	Mn	...	...
116	" Painsberg, Sweden (d)	Na	K	Rb 2	Ag 1	Cu 1	Ca	Ga 1	...	Tl 2	Fe	...	Mn	...	Pb 6
117	Pyrolusite, locality unknown (c)	Na	K	Rb 2	Ag 1	Cu 6	Ca	...	Tl 3	...	Fe	...	Mn	...	Pb 2
118	Mangauite, locality unknown (c)	Na	K	Rb 2	Ag 1	Cu 4	Ca	Ga	...	Tl 3	Fe	...	Mn	...	Pb 4
119	The same, 25 grams used	Na	K	Rb 2	Ag 1	Cu 4	Ca	Ga	...	Tl 3	Fe	Ni	Mn	...	Pb 4
120	Franklinite, locality unknown (d)	Na	K	Rb 2	Ag 1	Cu 1	Ca	...	...	Tl 1	Fe	Ni	Mn	...	...

TABLE IX.—Pyrites.

157	Iron pyrites, Wheal Lane, Cornwall (d)	Na	K	Rb 1	Ag 3	Cu 4	Ca	...	In 3	Tl 1	Fe	Ni 3	Mn	...	Pb 3
158	Marcauite, radiated, Dover (d)	Na	K	Rb 1	Ag 1	Cu 1	Ca	...	In 2	Tl 1	Fe	Ni 3	Mn	...	Pb 1
159	Iron pyrites, Esna, Norway (d)	Na	K	Rb 1	Ag 1	Cu 8	Ca	Ga 1	...	...	Fe	Ni 9	Mn	...	...
160	Pyrrhotite, Rom, Smalleuel, Norway (d)	Na	K	Rb 1	Ag 1	Cu 7	Ca	...	In 1	Tl 4	Fe	Ni 3	Mn	...	Pb 1
161	" Aurdalen, Bamle, Norway (d)	Na	K	Rb 1	Ag 2	Cu 9	Ca	...	...	...	Fe	Ni 1	Mn	...	Pb 6
162	Pyrites, Staffordshire (b)	Na	K	Rb 1	Ag 1	Cu 1	Ca	...	In 1	...	Fe	...	Mn	...	Pb 3
163	" Roschau (b)	Na	K	Rb 1	Ag 1	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 2
164	" Freiberg, Saxony (b)	Na	K	Rb 1	Ag 1	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 5
165	" Schemnitz, Hungary (b)	Na	K	Rb 1	Ag 5	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 1
166	" Isle of Elba (b)	Na	K	Rb 1	Ag 1	Cu 5	Ca	...	...	Tl 1	Fe	...	Mn	...	Pb 1
167	" Goslar, Harz (b)	Na	K	Rb 1	Ag 1	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 1
168	" Joachimsthal, Bohemia (b)	Na	K	Rb 1	Ag 1	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 1
169	Chalcopyrite, locality unknown (c)	Na	K	Rb 1	Ag 2	Cu	Ca	...	In 3	Tl 1	Fe	Ni 2	Mn	...	Pb 1

We have found lithium almost invariably in iron ores, and it occurs in Bessemer flame spectra; but, as a rule, it is not photographed, and our knowledge of its presence depends upon eye-observations of the red line. On this account it is not included in the tables. The presence of rubidium is very frequent, but where a note of interrogation (?) appears under this head, it implies that the lines in the spectrum were overpowered by closely-adjacent lines of iron.

It is a marked characteristic of siderites that they contain indium, and of magnetites that they contain gallium. Ores derived from the older rocks, such as bauxites from basalts, contain chromium, nickel, and gallium.

In clay-ironstones, gallium has been found in twenty-one out of fifty-one specimens; chromium frequently occurs along with it; and in the same ores both metals are occasionally associated with nickel.

Thallium is of rare occurrence in oxide ores of whatever variety, but it is frequent in pyrites. Indium, too, occurs in many specimens of pyrites, but gallium comparatively rarely.

Red hæmatites are ores of great purity.

It follows from this investigation that the ores used, when submitted to the same method of examination, afford us very decided indications of the lines to be looked for in the flame-spectra of the Bessemer blow.

THE IRON INDUSTRY OF HUNGARY.

BY DAVID A. LOUIS, F.I.C.

HAVING occasion to visit Hungary last year, the author took the opportunity of seeing the Millennial Exhibition at Budapest, and subsequently some of the ironworks and mining districts. The matter accumulated during these visits, as well as from literature published for the Exhibition, and at the Mining, Metallurgical, and Geological Millennial Congress, seemed to be of sufficient interest to place before the members of this Institute. The notes in question have, therefore, been collated so as to form a paper supplemental to that of the Ritter von Kerpely on the Iron Industry of Hungary in 1882, which appeared in No. II. of the Journal for that year, pp. 435-450.

In that communication it was pointed out that the iron industry of Hungary was of remote antiquity, but its progress had been considerably hampered by the want of a suitable supply of fuel, even although the waste gases were being duly utilised; the blast-furnaces were then worked with charcoal, which was becoming more and more scarce in their vicinity. At that time Hungary possessed an aggregate of forty-one pig iron works, with fifty-two blast-furnaces in operation, the yearly produce of the whole country amounting to 150,000 tons of pig iron and 17,600 tons of castings. Puddling furnaces, also worked with charcoal, were common, but a few Siemens regenerative puddling furnaces had been introduced, using wood or lignite in the producers as circumstances permitted, effecting thereby a great saving in fuel. In all, there were twenty-six double puddling furnaces and eighteen reheating furnaces heated in this manner. The finished iron produced at the time amounted to 73,784 tons; of tinplate, 14,270 tons; and of wire, 1500 tons, the last item coming entirely from the Rimamurany Works.

With regard to steel, at the State Railway Works at Resicza there were four converters and two Siemens furnaces for making open-hearth steel, 30,540 tons of steel being produced in 1881,

which was used for rails, tires, axles, plates, and merchant steel, the latter consuming 145 tons. At Diósgyőr a Bessemer plant had been completed, and was shortly to be started; the annual production of finished iron and steel in Hungary being then 112,272 tons. The iron ore districts were situated then, as now, in the following counties:—Gömör, Zips, Abauj-Torna, Sohl, Borsod, Marmaros, Hunyad and Krassó-Szörény. The deposits extend in a sort of semicircular belt from the west by north-west, north, and east to the south, uniting to form a characteristic group in the north-west. The ores are mostly carbonates in the upper beds, outcrops, and contacts merging into brown iron ore in depth, which varies with different localities. Other ores are frequently associated with the iron ore, but do not prevail in depth, and anyway present no great difficulties in separation. In the past, copper, lead, and silver mines and works existed where iron mines and works are now found, and the waste heaps of the earlier times provide material for the blast-furnaces of to-day. The annual production of iron ore of recent years has been as follows:—

1881 to 1885	582,435 tons of a value of about £140,952
1886 to 1890	658,768 „ „ „ £139,204
More recently	973,431 „ „ „ £196,273

And the output of iron and steel in Hungary is approximately as follows:—Pig iron, 350,000 tons; castings, 36,000 tons; Bessemer, basic, and open-hearth steel, 250,000 tons; finished wrought iron and steel, 260,000 tons; these having a value of about £2,625,000. The development of the iron industry in Hungary has, therefore, kept pace with the general industrial progress; and whereas the consumption per head of the population in Hungary was 35 lbs. in 1882, it is now about 53 lbs., in spite of the increase in the number of inhabitants. There is, however, still the lack of fuel to face in the production of pig that will keep that department comparatively backward. The other departments of the iron industry are more favourably situated in this respect, inasmuch as gaseous fuel is applied for heating, and this factor has, too, been brought to a fair state of efficiency, which, coupled with the good quality of the charcoal iron, has contributed in a great measure to the considerable development in the production of wrought iron and steel indicated, and to the

promising character of the produce, that could be remarked in many of the exhibits made at the Millennial Exhibition.

The iron industry in Hungary may, however, be regarded as restricted to five districts, characterised by geographical position, geological features, nature of the ore, and character of the fuel.

The first district, in the valleys of the Hernad, Sajo, Rima, Garam, and Vag, extends through the counties of Sohl, Gömör, Zips, Abauj-Torna and Borsod, and supports the blast-furnaces of Liker and Tiszolcz, and the fineries of Diósgyör, Salgo-Tarjan, Ozd, Nadasd, Zolyom-Brezo, Brezoin Sohl, and Kisgaram.

The second district is near the north-east frontier, including Dolha, Munkács, Kabolyapoljana, &c.

The third district, in the valley of the two rivers Koros, with plenty of ore and immense forests, and works at Boros-Sebes, &c.

The fourth district, in the valleys of the Temes and Karas, with rich veins of excellent ore, vast beech forests and coking coal, includes the great works of Resicza and Anina, and the smaller foundries of Ruszkitza, Ruskabanya and Nadrag, as well as the finery at Nandorhegy.

The fifth district is in Transylvania, with the enormous magnetic oxide deposit, as well as gigantic forests and great beds of lignite; here are the great works of Vajda-Hunyad, and the lesser ones of Govasdia, Kalan, and Kudsir, the latter a finery and tool-steel works.

Of these districts, the first, fourth, and fifth exhibit the greatest activity, but the third is, nevertheless, a district of considerable promise, and will doubtless do more in the future than it is doing at the present time.

It will now, perhaps, be well to glance at the state of the industry at the various centres. This subject was treated very thoroughly by Ministerial Councillor the Ritter von Kerpely in a communication entitled "The Metallurgy of Iron in Hungary at the time of the Millennium," of which, too, I have made much use; it was also briefly referred to in the official catalogue, and was more particularly illustrated by the displays made in the Exhibition itself; whilst personal inspection confirmed much, and considerably augmented the information accumulated in the manner just stated. Von Kerpely adopts the plan of taking the districts in geographical sequence, an arrangement which will also be followed in this paper.

The county of Sohl is situated at the north-west portion of the semicircular iron-bearing belt. It is regarded as the nursery of the iron industry in Hungary, but now only boasts of one blast-furnace at Libet, of the dimensions indicated in Table I. The ore smelted is a silicate containing 30–32 per cent. of iron. It is obtained from a contact vein, situated between Lower Permian dolomite and trachytic tuff, being some 26 feet thick, enlarging at places to a stockwork 400 feet thick. It is wrought by main roads, with cross levels at right angles. The annual output is 4000 tons; the ore being conveyed from the mine at Libet by an inclined road to the furnace, about seven miles distant. There the equipment includes a blowing-engine, consisting of two horizontal cylinders, driven, when there is water, by an overshot wheel, otherwise by a 30 horse-power engine; a calcining kiln and a cupola furnace. The blast is heated by the waste gases from the blast-furnace. The output is some 1100 tons of pig, and from 400 to 500 tons of castings. The pig is of excellent quality, as testified by exhibits, and is utilised in the neighbouring towns and at the State refinery at Brezo in Sohl. The State owns about 73½ per cent. of the whole concern, which is kept going even at a sacrifice on account of the poverty of the neighbourhood.

Gömör county is the leading producer of pig iron in Hungary; it has the richest ore, the largest deposits, most furnaces and greatest output. Of the deposits, one rests on chloritic schist, has a roof of clay and siliceous slate, and is divided into three ore bands by intermediate layers of clay, slate, and grauwacke. The ore bands vary in thickness from 3 to 100 feet; this deposit is proved from 2 to 2½ miles in the direction of the strike, which is east and west, and from about 300 to 330 yards on the dip, which is to the south. The ore is brown hæmatite, with pockets of clay iron ore and ochre, with carbonates at places. Another deposit between grauwacke and slates is divided into two by an intermediate layer of slate. The chief ore band is 32 to 150 feet thick; it has been traced for more than 760 yards along the strike, and about 220 yards in the direction of the dip. The ore is brown ironstone. There are other deposits of manganiferous and carbonate iron ores in this, the western part of the county, the Vashegy district. Here there are four great owners—the

Rimamurany Salgo-Tarjan Ironworks Company, who own a recorded area of some 440 acres; the Duke Philip of Coburg-Gotha has some 128 acres; the Government some 52 acres; and Heinzelmann's Ironworks Company some 62 acres. Owing to the tender character of the ground and the width of the deposits, the winning is effected by a system of square work and stowing. The output of the four properties, taken in the order as above, was for 1895 approximately 137,956, 10,000, 20,300, and 1600 tons. The ores, as has been noted, vary in character, and consequently also in chemical composition. Taking from the various numbers published the extremes, we find for the ores of three of the four properties when dried at 100° C. the following approximate percentages:—

	Iron.	Manganese.	Copper.	Phosphorus.	Sulphur.
First property .	18-56	1-15	0·003-0·05	0·136-0·485	0·013-0·186
Second property.	27-51	$\left\{ \begin{array}{l} \text{Mn}_2\text{O}_3 \\ 0·4-13 \end{array} \right\}$	none-0·2	trace-0·68	0·02-0·10
Third property .	39-55	0·2-12	0·009-0·1	0·13-0·74	0·03-0·42

The Rimamurany Company have two localities for working these ores, mixed to a certain extent with other ores; one place is Liker, the other Nyustya. To the former the above ores (raw brown ironstone, calcined spathic iron) are brought by an aerial ropeway; the other ores, limestone, coke, &c., by a special siding from the State railway. There are three blast-furnaces, of which the particulars are given below, the most recent of which is illustrated in Plate VIII. They are fitted with Lang's central take-off apparatus. The blast is obtained from three horizontal compound engines, and is heated in eight Cowper stoves, each with 43,000 square feet of heating surface. Each furnace has six tuyeres. There are hydraulic lifts for raising the charges, electric light, storage bins for ore, limestone and coke, &c.

The annual production of the three blast-furnaces is 77,000 tons, which, according to the quality, is destined for the puddling furnace, for basic treatment, or for the open-hearth in the company's own works at Salgo-Tarjan and Ozd.

The blast is furnished by three horizontal blowing-engines

with eleven boilers. The engines are compound, with high-pressure cylinder 43·31 inches diameter, and low-pressure 64·96 inches; the air-cylinders being 88·58 inches; the stroke 66·98 inches, and 25 per minute. The boilers are gas-heated water-tube, each with a heating surface of 2415 square feet. Pumps supplying 60 cubic feet of water a minute are worked by a 60 horse-power Girard turbine in the river Rima, which also furnishes power to the workshops; there is a steam-pump, however, in reserve.

The ropeway, of $8\frac{1}{2}$ miles extent, is driven by a 100 horse-power steam-engine, is provided with 640 buckets, each of a capacity of $6\frac{1}{2}$ cwts., and carries 250 to 300 tons a day. There are employed 450 men, foremen, &c., at the furnaces, and 80 at the ropeway.

The chemical character of the iron produced is here set forth:—

	Si.	Mn.	Total C.	Graphite.	Cu.	P.	S.	Fe.
White . . .	0·30	2·40	2·60	0·28	0·007	0·56	0·037	94·096
Mottled . . .	0·96	3·06	3·73	3·01	0·006	0·59	0·054	91·55
Grey . . .	3·15	1·86	3·96	3·22	0·004	0·62	0·048	90·36

At Nyustya, less than two miles from Liker, the same company have a blast-furnace and foundry for the production of castings from the Vashegy and Rakos ores, which are brought by means of a ropeway. The blast-furnace is about 33 feet high, 9 feet 4 inches diameter at the bosh, 4 feet 4 inches at the throat, 4 feet 6 inches in the crucible. It is worked with charcoal obtained from the company's forests, and furnished with blast by a three-cylinder vertical blowing-machine worked by a 30 horse-power water-wheel, the blast being heated by two Gjers' stoves, having together 3655 square feet heating surface. The yield is about 55 to 60 tons of grey pig iron weekly, most of which is used up in direct castings, but a cupola is also used for casting work; the yearly output is about 2000 tons of pig iron and 3000 tons of castings; 110 workers are employed at this place.

The character of the iron and slag is shown below:—

	Si.	Mn.	C.	Cu.	P.	S.	Fe.	
Grey pig iron . .	1·5	1·8	3·69	0·009	0·65	0·906	92·376	
	SiO ₂	Al ₂ O ₃	MnO.	FeO.	CuO.	MgO.	Alkalies	P ₂ O ₅
Slag . .	52·10	6·06	4·45	1·71	30·28	3·69	0·043	0·60

The exhibit of this company will be referred to later on.

The Government works of this district are at Tiszolecz. There are two blast-furnaces, one an old charcoal furnace, the other a coke-furnace of the dimensions given in Table I. appended. The first serves for the production of pig iron for the foundry, the second for white pig iron for the puddling furnaces; both furnaces have a central take-off, and are connected by an iron bridge 220 feet long with the railway depôt, so that the charging can be conducted direct from this point.

Vashegy ore is smelted in the charcoal furnace, but for the other furnace it is mixed with reheating cinder and with ore from deposits of spathic ore in clay slates at Berglehne; these deposits are traversed by quartz veins containing copper pyrites and fahlore. The spathic ore is submitted to a preliminary calcination; the limestone is obtained in the neighbourhood, and the coke from Ostrau and Silesia. The output is 9692 tons per annum, and the composition of the pig iron is as follows:—

	Si.	Mn.	C.	Cu.	P.	S.
White pig iron . .	0·84	1·08	2·07	0·06	0·07	0·07
Medium grey pig iron	1·10	1·79	3·12	0·167	0·125	0·103

These are mainly used in the Royal works at Brezo in Sohl, but some foundry pig iron goes to the Kisgaram works.

At the Duke of Coburg's works there are two furnaces, but for want of fuel only one is in blast; it smelts 4000 tons of coarse and 6000 tons of fine Vashegy and Rakos ore; the mines being three to four miles or so away, the ore and the charcoal are packed down. The furnace is 43 feet high; the blast furnished by a two-cylinder vertical blower worked by a 30 horse-power steam-engine, the output being 3752 tons in 1895.

The Heinzelmänn works is situated six to ten miles from the mines; the ore is carted, but an aerial ropeway is projected. There are three 40-foot furnaces, furnished with from three to five tuyeres; there is a double-cylinder blowing-engine, worked by two engines of 40 and 100 horse-power respectively, and the blast is heated by passing through heated tubes. The fuel is charcoal, half hard, half tender. The output is 6200 tons, of which 3000 tons consists of castings, of which three-fifths are direct from the blast-furnace and two-fifths from cupolas.

Turning now to the Dobsina section of the Gömör iron fields, we again have spathic ore with brown ore at exposed places.

The deposits are from 20 to 80 feet thick, and rest on diorite. They are rather inaccessible, and as the ore is only 28 to 35 per cent. stuff, the exploitation is not commensurate with the development or magnitude of the deposits. The deposits at the headwaters of the river Sajo are more favourably situated, and again is found the association of quartz and fahlore, and also calcspar and ankerite. The great owners are the Duke Philip of Saxe-Coburg-Gotha, who quarries about 10,000 tons of ore, and the township of Dobsina, which puts out 12,000 tons of ore to supply two charcoal blast-furnaces 40 feet high, producing about 6500 tons of pig for the finery. The Government is the next owner, but does not work these mines, and Count Géza Andrassy, who has a vast acreage, produces annually 75,000 tons of ore, containing about 38 per cent. of iron, 2 per cent. of manganese, 0.02 per cent. of phosphorus, and 0.15 per cent. of sulphur. A tramway with inclines is used for transport of the ore to the blast-furnaces, which are eight in number, from 40 to 60 feet high, with an annual production of from 4000 to 6000 tons each; blowing-engines worked by water-power are used. Four of the furnaces provide Bessemer pig, three for the finery, and one for the foundry. The annual consumption of charcoal is 30,000 tons. Count Dionys Andrassy produces 15,700 tons of ore, which is smelted in a 42-foot furnace, producing 4000 tons of castings, most being direct from the blast-furnace. Another firm extracts and uses 18,000 tons of the ore of this neighbourhood.

Milos Milosevich has made a special communication concerning the development of the pig iron industry in Gömör county. He shows how the local circumstances have favoured it, strong deposits of ore and dense forests, so that the industry has flourished there since the Middle Ages, and the methods and practices have been handed down from father to son, so that the ironworkers have characteristics that distinguish them from the other local inhabitants. As regards recent progress, it is pointed out that in 1867 the ore output of the county was 111,228 tons, employing 1639 people. In 1894 the ore output was 320,617 tons, with 2145 workers; or, while the output had increased nearly threefold, the number of workers employed had only increased by about one-third, this being due to the improved

methods of mining. Forty years ago the production of pig amounted to 29,700 tons; in 1885 it had increased by 4.1 per cent. to 122,000 tons; in 1895 by 6 per cent. to 178,000 tons; and per head of population Gömör produced about 1874 lbs., England 360 lbs., Germany 196 lbs., and Hungary 36 lbs. in 1893.

In the neighbouring county of Zips the ore deposits are more extended and richer, but the furnaces are fewer and less important, much of the ore being exported. The Archduke Frederic has a large area at Göllnitz and elsewhere, and puts out 100,000 tons a year. The ore is picked by hand into three classes—prills, lumps $1\frac{1}{2}$ to $\frac{3}{4}$ -inch; smalls, less than $\frac{3}{4}$; copper pyrites, &c., being discarded. Eighty thousand tons of the ore is calcined in twenty-three calcining kilns and one reverberatory, yielding 50,000 tons of calcined ore, all being exported to Silesia. The Upper Silesian Railway Supply Company work on a large scale, at Iglo and elsewhere, a deposit of iron spar in clay slate which in depth not only increases in magnitude, but also loses the fahlore occasionally met with above; they have electric drills in their mines, because labour is scarce, their own ropeways and railway, 30-inch gauge, 11.3 miles long. The heavy waggons weigh 2 and carry 7 tons, and are run in trains up to forty-five in number, drawn by locomotives. They have twenty-eight calcining kilns, and calcine some 82,562 tons of ore per annum, yielding 53,378 tons of calcined ore, which, along with 13,574 tons of smalls, is exported. The percentage composition of the ore before and after calcination is as follows:—

	Fe.	Mn.	SiO ₂ , &c.	MgO, CaO, &c.	Al ₂ O ₃ , &c.	Loss on Ignition.
Crude spathic ore	38	1.5	9	0.14	1.0	30
Calcined	53	2.0	11	...	1.5	0.8-1.5

The calcining kilns yield 7 to 8 tons of calcined ore a day, or in winter even as much as 12 tons, with a consumption of 4 parts of coke per 100 of calcined product. The Witkowitz Iron Company work some deposits of iron ore; one of them is divided by a gabbro parting into two veins; the ore is spathic, but is associated with quartz, copper pyrites, and a fahlore carrying mercury; a washery is to be installed to separate these minerals from the iron ore. The company puts out 100,000 tons a year, and exports more than 20,000 tons of calcined ore to Silesia and

Witkowitz, which is produced from 30,000 tons of mined ore, in eighteen furnaces. In Zips county there are various other strong deposits that are beginning to attract the attention of capitalists, and one company is erecting two coke blast-furnaces for a production of 40,000 tons, to work a red hæmatite deposit that has been proved for two miles and to a depth of 160 to 200 feet; the beds have a thickness of from 10 to 30 feet, and the iron in the ore varies between 32 and 59 per cent. There are two old charcoal furnaces at Krompach, 36 feet high, that still produce 6000 to 7000 tons of pig iron annually.

The second large ironworks of Zips county belong to the Duke Philip of Saxe-Coburg-Gotha, with a mining area of over 470 acres, some of which is exhausted, and some of which, owing to unfavourable situation and conditions, is little developed. Hitherto the ore has been carted to the smelting works at Strazena, five miles away, on the borders of the county, and an equal distance from Dobsina, but now ropeways are to be constructed to connect the mines with the works. It is noteworthy that at Strazena, at the beginning of the eighteenth century, there were copper smelting works, which were engaged not only in the supply of copper castings, but also in the sale of cobalt and silver.

The Strazena works comprise two charcoal blast-furnaces, one old on pillars, the other more recent on columns, both $34\frac{1}{2}$ feet high, with a diameter of $39\frac{1}{2}$ inches at the tuyeres, $109\frac{1}{4}$ inches at the boshes, and 51 inches at the throat. There are two vertical blowers of two and three cylinders respectively, operated by a 20 horse-power water-wheel, and a 30 horse-power steam-engine; the blast is heated by the waste gases and is applied by two tuyeres in each furnace; the combined output from both furnaces is 7418 tons annually. The charge is made up of 80 per cent. calcined and 20 per cent. raw ore, the fuel being one-third hard, and two-thirds soft charcoal. There are eight calcining kilns.

Another big mining property of 493 acres, formerly Count Csarky's, and the oldest works in Hungary, has bands of spathic ore 15 to 20 inches thick in clay and chloritic slates, opened up for $1\frac{1}{2}$ mile, and worked for a length of 3150 yards, yielding 5000 to 6000 tons a year; the ore contains—iron 30 to 40 per cent., manganese 2 to 3 per cent., a little copper and quartz,

and a notable quantity of manganese. The ore is treated by three calcining kilns with an output of 1800 tons a year, and a 32-foot blast-furnace producing 2158 tons of grey pig annually, which with 400 to 500 tons of purchased pig is used in a well-appointed foundry and bloomery. A small blast-furnace, yielding 1800 tons a year, completes the furnaces working in this county, although this account by no means exhausts the deposits that are known, and have been proved to a considerable length and depth, but are somewhat inaccessible.

Abauj-Torna, the county to the south-east of Zips, has well-developed mines, producing 29,400 tons of ore at Jasso that is sent to Liker, and others supplying two blast-furnaces, one yielding 2000 tons, the other 650 tons of castings and 350 tons of pig, this all being the property of the Rimamurany company. In Borsod county, at Rudobanya and in the vicinity, there is a single extensive deposit upon which the area conceded for mining is 1100 acres, with prospecting rights over a farther extensive area. The deposit lies on Triassic limestone, and is overlain by Tertiary marls; it is of the character of a valley filling, is frequently interrupted, but has been traced for $3\frac{1}{2}$ or $3\frac{3}{4}$ miles, is 209 to 437 yards across, and has a thickness varying from $6\frac{1}{2}$ to $65\frac{1}{2}$ feet. In some parts the ore is very pure, in others it is mixed with dolomitic chalk, and occasionally also with heavy spar and native copper. It is a manganiferous ironstone, frequently associated with brown hæmatite, but rarely with red; the deposit is pockety throughout. The following numbers give an idea of the composition of this ore:—

	Fe ₂ O ₃ .	SiO ₂ .	Al ₂ O ₃ .	MnO.	CaO.	MgO.	CuO.	P ₂ O ₅ .	BaSO ₄ .
Crude ore .	68.57	10.10	2.24	4.03	1.40	1.02	0.11	0.06	3.44
Calcined ore .	70.30	10.72	2.25	3.91	1.15	0.73	0.09	0.07	4.00

The ore is extracted by open-cast working, the sedimentary overburden being generally removed by two Ruston-Proctor bucket excavators, each requiring a 10 horse-power steam-engine, with a capacity of 106,000 to 126,000 cubic yards a year, and effecting a saving of 22 per cent. over manual labour. The annual output is about 230,073 tons of iron ore, of which 15,000 tons is used in the county, the rest going to Witkowitz. For calcining, the ore is conveyed on a 20-inch gauge railway to the

kilns; they are heated by gas admitted below the upper chamber, are circular, and have the form shown in Plate IX., being constructed from the plans of the director, M. E. Holz, and serve for the coarse ore, yielding from 65 to 80 tons of calcined ore per twenty-four hours; there are four of these furnaces. The fine ore is calcined in a Möser reverberatory with a long inclined bottom, exposing a heating surface of 344 square feet, and capable of firing 40 to 50 tons of calcined ore per twenty-four hours, with a consumption of 18 to 20 lbs. of brown coal per ton; the loss in calcining being 20 per cent. There are other deposits of iron ore in Borsod County, but they are unimportant, and the same may be said of the north and north-east of Hungary generally—the whole production from the four blast-furnaces in that region being 4500 tons of pig iron and castings combined.

Turning now to the south-east, Hunyad county is the first encountered, and in it are the strongest brown iron ore deposits of Hungary. They played an important part in the production of iron in very remote times; in fact, there was exhibited in the Exhibition a portion of a furnace found near Gyalar. It had been cut out of the rock, and is supposed to date a thousand years back. It is semicircular in girth, is 2 feet in diameter at the chimney, and 1 foot outside at the bottom of the hearth; its total depth being $5\frac{1}{4}$ feet, being about 4 feet below the chimney. It is lined with refractory material (see Fig. 1). A block of iron was found in it. The working pit is about 3 feet from the centre of the furnace, being roughly rectangular, and about 2 feet square and 1 foot deep. The chimney is 5 inches in diameter, and it will be observed that a charging platform was erected, and that the furnace was furnished with a cover. The rocks of the district are highly metamorphic, being principally undulatory beds of clay, slates, and then micaceous schists, containing in some places much felspar, and even giving place to gneiss at times; in addition, crystalline limestones and many other sedimentary rocks are well represented, whilst amongst eruptive rocks trachyte and basalt figure. The lateral extension of the deposits is very variable; in fact, they appear to consist of a broken series of irregular masses. The particular mass owned by the State at Gyalar is over 500 feet thick, and consists almost exclusively of limonite embedded in micaceous schists and

limestone, the former forming the roof and walls. Limestone and ankerite traverse the ore deposits in irregular beds and pockets. It is worked open-cast, the output being 138,000 tons; the composition of the ore being—

Fe_2O_3 .	MnO.	SiO_2 .	Al_2O_3 .	CaO.	MgO.	P_2O_5 .	S.	CuO.	Fe.
91.39	0.34	1.99	...	0.33	0.32	0.03	0.12	trace	63.93

The ore is conveyed partly by horse-tramway to a small foundry at Govasdia, by a road $3\frac{1}{2}$ miles long, that is for some distance

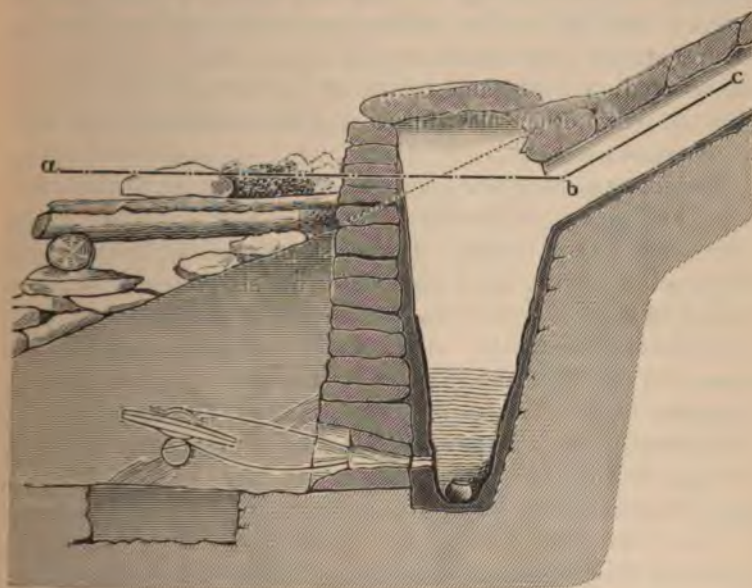


FIG. 1.—Ancient Blast-Furnace.

tunnelled, and ascends and descends inclines. The other part of the ore is transported by two ropeways to the foundry at Vajda-Hunyad. One of these ropeways, 19 miles long, also serves the charcoal store at a town on the way, and on the return journeys conveys coal, building materials, clothing, victuals, and forage. The other ropeway is $6\frac{1}{4}$ miles long, and takes ore to the coke blast-furnace at Vajda-Hunyad.

The Govasdia blast-furnace, with closed throat, is 36 feet high

5½ feet between the tuyeres, 8½ feet at the boshes, 5 feet 7 inches at the throat, and of a capacity of 1589½ cubic feet; the fuel is exclusively beech charcoal. The blast is obtained from a two-cylinder vertical blower, worked by an overshot water-wheel of 30 horse-power. The product is grey, white, and mottled pig iron, and a small quantity of direct castings. Heavier castings are run from a cupola. Its annual output is 8124 tons of pig, and 141 tons of castings. This furnace was not sufficient to keep pace with the development of the mines at Gyalar, so the foundry at Vajda-Hunyad was started with two charcoal furnaces. The one was blown in in 1885, and has worked up to the present without interruption; the other was blown in a year before, whilst a third was erected in 1890, and blown in in 1891, and is shown in Plate X. Two other blast-furnaces differ somewhat from these in dimensions.

The furnaces, supported on cast-iron pillars, are closed both throat and mouth, with central take-off. They have four tuyere holes, each 4 to 5 inches. The blast pressure is 2·36 to 3·14 inches of mercury; it is furnished by six vertical cylinders worked by a turbine and two steam-engines of 100, 50, and 150 horse-power respectively. The blast is heated by three Whitwell stoves 39½ feet high and 16½ feet in diameter, and three iron pipe apparatus of considerable heating surface. The three charcoal blast-furnaces produce about 49,396 tons of pig, and 1300 tons of castings, destined for consumption in the State works. The output of Govasdia and Vajda-Hunyad combined being insufficient to supply the State fineries and steelworks at Diósgyőr, a coke furnace of 40,000 tons capacity was projected in 1894, and blown in in 1895. Its total height is 65½ feet, its working height 59 feet, with a capacity of 10,170 cubic feet; the diameter being 7½ feet in the crucible, 18½ feet at the boshes, and 15 feet 1 inch at the mouth. It is furnished with six tuyeres. The output is 100 tons Bessemer pig iron daily.

The blast is furnished by a quick-running, 50 to 60 strokes of 53·15 inches, compound blower, with high-pressure cylinder 28·44 inches in diameter, low-pressure cylinder 45·28 inches in diameter, and air-cylinder 81½ inches in diameter; each cover is fitted with thirty suction and fifteen pressure valves, very light and frictionless, so together 180 valves, any of which can

be readily changed even when the engine is running quickly. The blast is heated by three Whitwell stoves, 52½ feet high by 19 feet 8 inches in diameter. Excellent models of the furnace (which is of most modern type) and stoves, also samples of the produce and the materials, were shown in the Exhibition; moreover, further details are furnished in von Kerpely's valuable paper.

In this county the Cronstadt Mining and Smelting Company have mines yielding 24,000 to 25,000 tons of ore, which is worked in three furnaces at Kalan, originally designed for coke and coal, and of which one worked with coke and one with charcoal are in blast. The dimensions, &c., are about—height, 40 feet; diameter of crucible, 4 feet; boshes, 14½ feet; mouth, 11¾; capacity, 4132 cubic feet; tuyeres, 4. There is a 180 horse-power blowing-engine; the output is 10,000 tons per annum, part of which is used in direct casting, whilst some 2000 to 2500 tons of castings, principally parts of stoves, are cast from cupolas. The Nadrag Iron Company mine iron ore at Gyalar, which they cart to Vajda-Hunyad railway station, whence it is conveyed to Govasdia, where it is transhipped and taken along a light railway to the works at Nadrag.

At the eastern extremity of Hungary, in the county of Udvarhely, there is a deposit of brown iron ore which is mined, producing 3738 tons of ore, which is smelted in a 39-foot open-mouthed blast-furnace, yielding 600 tons of pig iron and 600 tons of castings, partly from the blast-furnace direct, and partly from two cupolas.

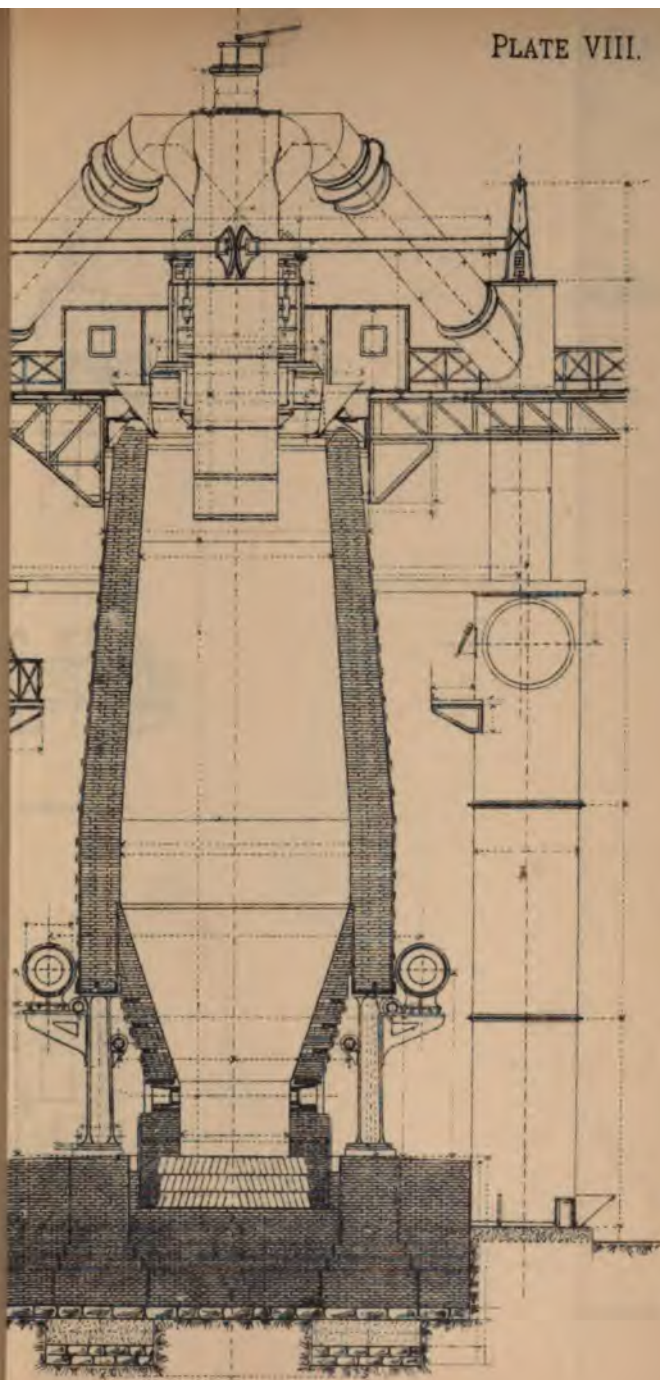
The most southerly iron-producing county of Hungary is Krasso-Szörény, and the principal makers are the Austria-Hungarian Privileged State Railway Company. Iron and other ores occur here along with crystalline limestone in a contact formation between trachyte and crystalline schists; the crystalline limestone in which the iron ore occurs rests on the trachyte for the most part, but less frequently on gneiss, syenite, or mica schist. The deposit extends from south to north for 9¾ miles, but the extremities are not of much good. The ore is found in masses and in stockworks as much as 100 feet thick, associated with garnetiferous rock, and sometimes even bedded with massive garnet, augite, or amphibole. The garnet attains at times a

thickness of 650 feet and more. In the northern part of the deposit at Vaskö, iron ores prevail, mainly magnetic oxide; in the southern portion, at Dognacska, lead and copper ores prevail, and brown and red hæmatite, as well as magnetic oxide are found. The deposits are worked open-cast or underground according to circumstances. In the extreme north of the district blocks of excellent red hæmatite and magnetic oxide, 100 cubic feet or more in bulk, are found in fault fissures, along with varying sized lumps of all kinds of rocks of the neighbourhood, which are separated from the ironstone by a system of washing, which furnishes 3000 to 4000 tons of iron ore. The ore is conveyed to the railway by an inclined tramway, and by rail to Bogsan or Resicza, some being transhipped at Bogsan for Anina. The output of ore at Vaskö is 101,266, at Dognacska 29,203 tons. The washed ore contains 45·29 per cent. iron and 18 per cent. silica: the other ores average—

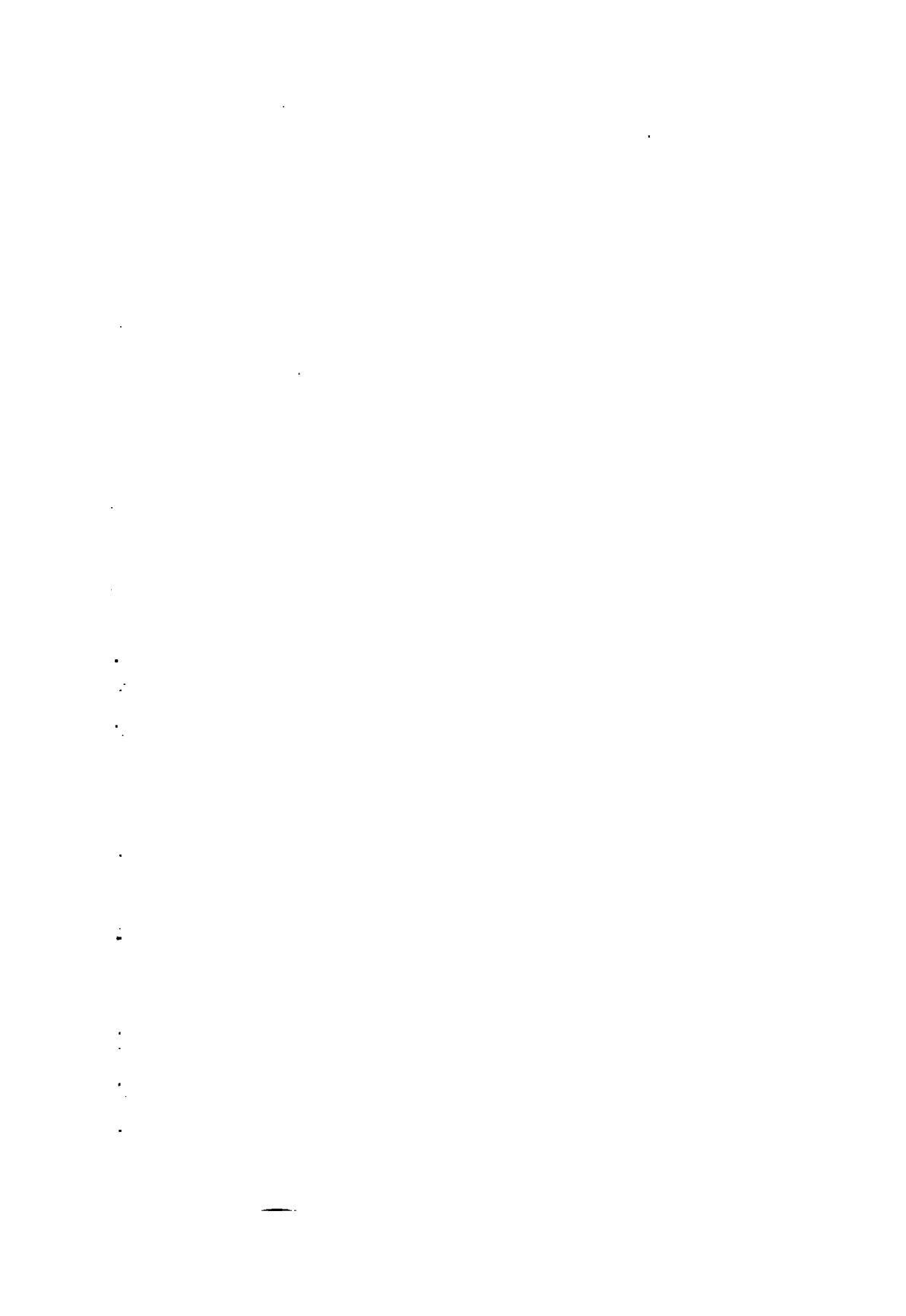
	Fe.	Mn.	SiO ₂ .	Al ₂ O ₃ .	CaO.	MgO.	P ₂ O ₅ .	S.	Cu.
Vaskö . . .	41·5	1·4	20·4	4·0	9·0	2·0	0·2	0·09	0·02
Dognacska .	34·0	0·3	18·3	3·0	7·0	0·4	01·4	0·15	0·16

At Resicza there are two charcoal blast-furnaces 55½ feet high, and 4520 cubic feet capacity, of modern construction, and one coke blast-furnace 65½ feet in height and 9781 cubic feet capacity. The blast is furnished by three engines, but a new compound horizontal engine of 800 horse-power is being constructed to do this work. It is heated by eight Whitwell stoves, six of which are 52½ feet high, with 3281 square feet heating surface, and two are 64½ feet high, and over 6000 square feet heating surface. The greater part of the iron ore is calcined in furnaces 20 feet high with a maximum diameter of 14½ feet, of which there are six, each of a capacity of 6½ tons a day, fed with small coal. The charcoal furnaces produce together per annum 23,000 tons of Bessemer pig, and the coke furnace as much as 22,000 tons. There is a large foundry attached to the works, with six reverberatories and two cupolas, which produce 3800 tons of castings, principally parts of machinery, grooved and hardened rollers, pipes, and merchant castings.

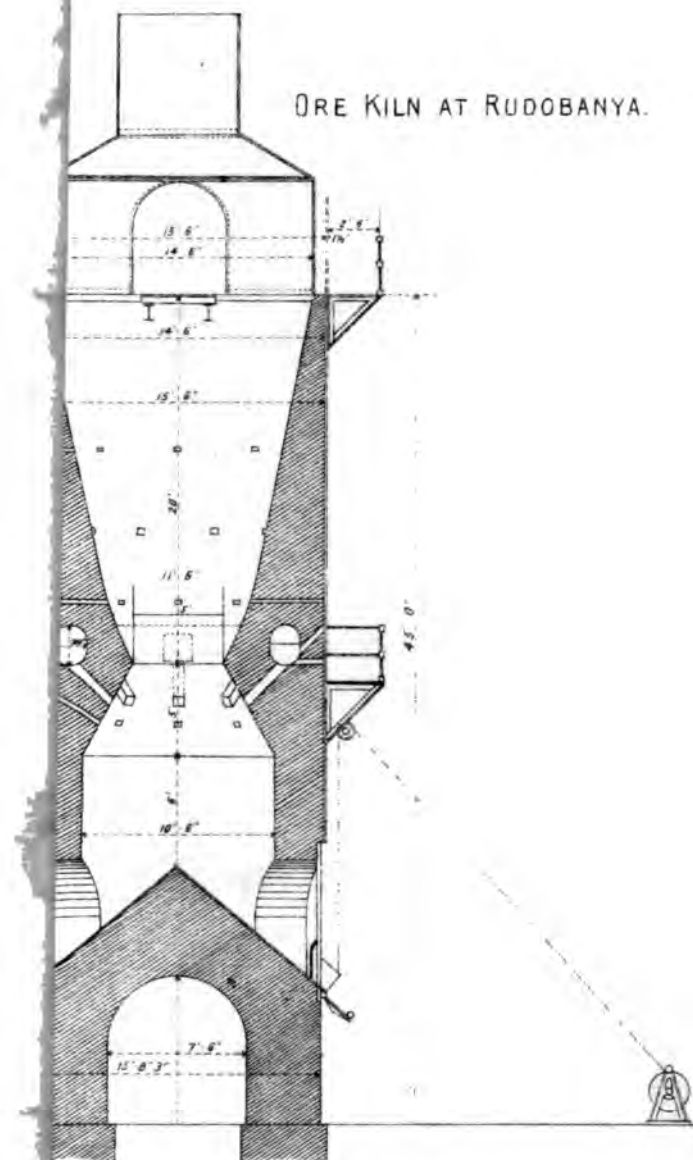
The blast-furnace at Bogsan is 44 feet high, 4½ feet in the



THE BLAST FURNACE AT LIKER



ORE KILN AT RUDOBANYA.



CHARCOAL
BLAST FURNACE
AT VAJDA-HUNYAD.

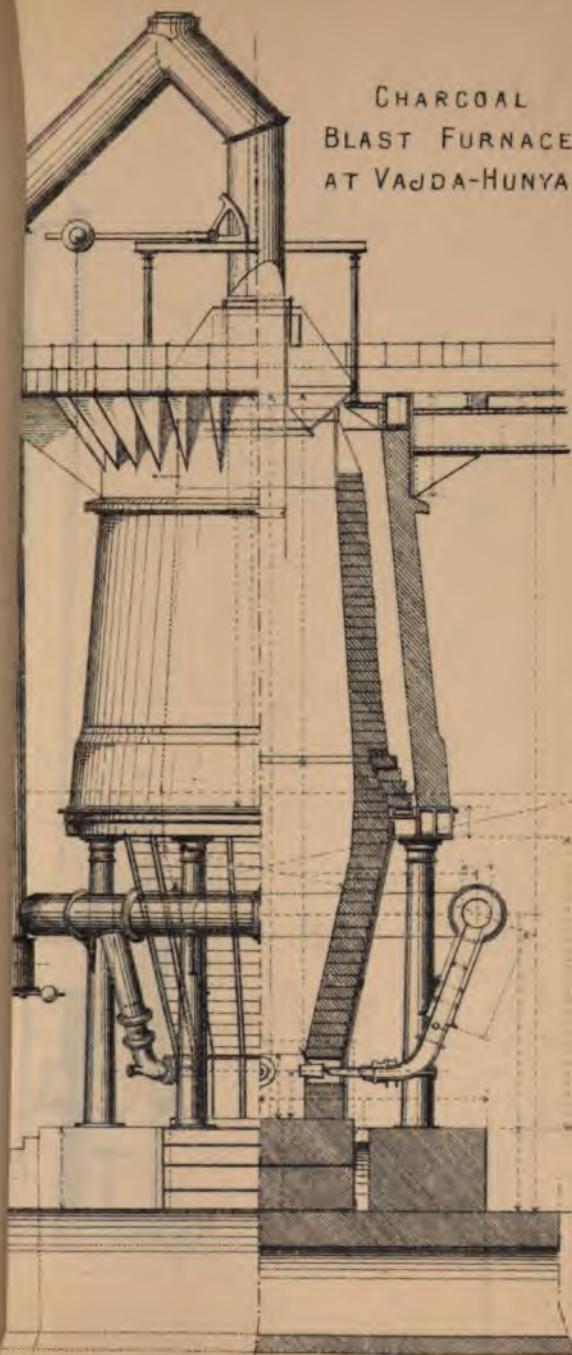
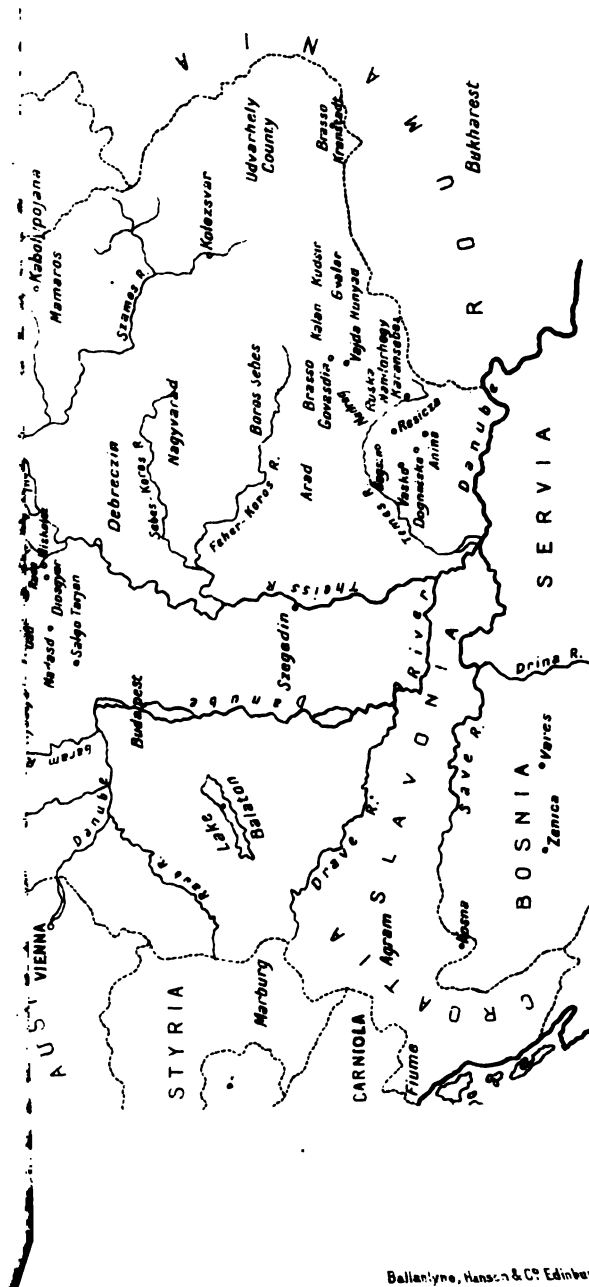


PLATE XI.



1. The first part of the document is a list of names and titles, including "The Hon. Mr. Justice" and "The Hon. Mr. Justice".

crucible, 11 feet 5 inches at the boshes, 8 feet 4 inches at the mouth, with a capacity of 2422 cubic feet and four $3\frac{1}{2}$ -inch tuyeres, producing 4820 tons of pig iron a year.

At Anina there are two blast-furnaces, one worked with coke and coal of the district, the other with charcoal and coal. The furnaces are about $62\frac{1}{8}$ feet high, and $6\frac{1}{2}$, $15\frac{3}{4}$, and $8\frac{3}{4}$ feet in diameter in the crucible, boshes, and mouth respectively. With tuyeres of $5\frac{1}{2}$ inches they can produce 34,000 tons of pig. The blast is provided by a 120 horse-power vertical engine, and heated by three Whitwell stoves $52\frac{1}{2}$ feet high and of 3281 feet heating surface. In the foundry associated with this works 6000 tons of castings, chiefly for railway purposes, stoves, &c., are produced from three cupolas and one reverberatory, and 200 pipes, from 3 inches to 4 feet in diameter, can be turned out per diem.

There are other small workings on the boundary of Krasso-Szöreny on an extension of the Hunyad deposit, which is worked up at Ruszkitza, where two charcoal furnaces work alternately; they are 40 feet high with a capacity of 2119 cubic feet, the blast being furnished by a two-cylinder horizontal engine worked by a 70 horse-power turbine. The output is 1000 tons white pig, 2400 tons castings, mostly direct. At Nadrag, the company of that name, already referred to, have an excellently appointed foundry; they have also a single blast-furnace in Temes county, producing 7000 tons of pig iron and 2200 tons of well-finished castings.

It may here be noted that the chief private Hungarian iron undertakings are, following the geographical order adopted, the Union Iron and Steel Manufacturing Co. (Sohl), the Rimamurany Salgo-Tarjan Iron Works Co., and the Privileged Austria-Hungarian State Railways, the last two being the result of the union of several smaller undertakings, from which union considerable benefit has been derived. These three will receive special attention now.

I should first, perhaps, mention that the Government exhibits, to which, in fact, I have already referred, were very complete in other departments as well as iron, but to the latter I am now restricting myself; the royal foundries at Kabolyapojana, Kisgaram, Kudsir, Libetbanya, Tiszolcz, Vajda-Hunyad, and
1897.—ii.

Zolyom-Brezo (Brezo in Sohl) all being represented. They give employment to 5570 hands, and work iron and steel of an annual value amounting to about £660,000. The exhibits comprised specimens of ores, fluxes, fuels and produce, to which were appended labels with the numbers from the analyses; plans, reproductions, models, and reliefs of the mines and examples of the appliances and of the methods of working; plans and drawings of the various works, and pictorial representations and models of blast-furnaces; also particulars of dwellings, hospitals, laboratories, &c., making an interesting and complete display. It should here be added that the Rimamurany Co. and the Privileged State Railway Co. made equally comprehensive and complete displays in their own pavilions, and other firms were well represented, if not to quite such an elaborate extent; and, without particularising, it may be said that in general the character of the iron and steel, pig or ingot or manufactured, as demonstrated by fractures and tests, was very good. Here are a few examples of tests:—

	Tensile Strength, Lbs. per Sq. In.	Contraction per Cent.	Elongation per Cent.
State puddled iron plate . . .	46,500	31.1	16.5
„ „ „ „ „ . . .	48,900	30.5	14.0
„ Open-hearth steel angle . . .	60,880	54.5	24.0
„ „ „ „ „ . . .	64,570	53.7	24.5
„ „ „ channel . . .	55,750	59.9	26.5
„ „ „ „ . . .	60,880	54.5	24.0
Rimamurany basic rails . . .	83,060	30.1	20.0
„ „ „ „ . . .	82,960	56.2	22.5
„ „ „ plate . . .	64,570	64.6	31.0
„ „ „ „ . . .	54,620	69.4	28.0
„ „ „ girders . . .	60,170	66.4	29.4
„ „ „ „ . . .	52,970	58.5	32.7

The spirit with which the private firms entered into the national display that was made at the Exhibition may be gathered from the following data relating to the area covered by their special buildings and the money expended on them. The Rimamurany Salgo-Tarjan Ironworks Company's building covered an area of 960 square yards and cost £2333; the Privileged Austria-Hungarian State Railway Company's pavilion, 576 square yards and £4167; the "Union" Company, 120 square yards and £417;

and iron and steel formed a prominent feature in many other buildings, notably of the Machine Factory of the Hungarian State Railway, which contained trophies of manufactured iron and steel from Diósgyőr, and some perfect test-pieces exhibiting considerable excellence, cast steel wheels being an important feature. The Rimamurany building was an imposing circular domed structure with various bays, and contained one of those comprehensive exhibits such as has been already referred to; the mines and their produce, models of blast-furnaces and steel furnaces, a 10-foot plate-mill, plans and illustrations of the works, pig iron castings, steel of all sections, bars of all shapes, girders, angles, &c.; wire, galvanised, barbed and not; nails; plate steel, black, galvanised and tinned; and the housing, sanitary, hospital, and educational arrangements. This great company is the result of the amalgamation of two great enterprises, that were themselves each coalitions of various smaller undertakings. The history of the company's works and properties therefore dates back a hundred years or so, and teems with interest, which is greatly enhanced by the fact that by travelling in the country there is ample evidence still to be seen testifying to the veracity of the recorded statements. But I must merely touch on this fascinating portion of my Hungarian experiences, for fear of extending this paper beyond the size usually allotted to an entire volume of the Institute's Transactions. Suffice it to say that the properties form two main groups:—I. The forests, mines, and blast-furnaces in the valleys of the Rima and Murany rivers, and the mills at Ozd-Nadasd. II. The Salgo-Tarjan refinery and coal-mines. The forestry department is naturally of great importance, as it furnishes the charcoal, mine timber, building timber, and wood for fuel; it receives a considerable amount of attention, but scarcely concerns us. The same, perhaps, may be remarked about the coal-mines; they are, however, worked very systematically, and exhibit some great mining skill, with due appreciation of modern appliances for dealing with the coal. Some 233,775 tons of coal, worth £58,444, is produced per annum from the various mines belonging to the company. The iron mines of the company are situated at Vashegy and Rakos in Gömör county, Jaszo and Rako in Abauj county, and Schmölnitz and Slovinka in Zips, to which casual reference has already been made, and will probably suffice.

Vashegy mine produces about 96,300 tons of ore annually, and employs 420 workpeople; the ore being of mixed character—spathic ore, with an average of 38 per cent. of iron, 8 of manganese, and 10 insoluble in acids; black ore, with 46 of iron and 10 of manganese; all varieties of brown ore (limonite), with 46 of iron and 4 of manganese; also hæmatite.

Rakos mine, a mile and three furlongs away, has recently been equipped with a compound winding-engine and two Worthington pumps with a capacity of 264 gallons a minute, with two boilers having 1632 square feet of heating surface, the shaft having been sunk to a depth of 160 fathoms. The ore is a 38 per cent. ore, siliceous limonite above, siderite below; the output is some 50,000 tons a year, which is conveyed $2\frac{1}{2}$ miles by a $20\frac{1}{2}$ -inch gauge railway; 185 people are employed. At Jaszo a spathic ore, 39 per cent. iron, 2.5 manganese, mixed with quartz and copper and iron pyrites, is produced, the output being 29,400 tons a year; the ore is roasted on the spot, and conveyed by the State Railway to Likier. Here electrical drills are employed and 250 workpeople.

The Rako mine is a 30 to 34 per cent. brown ironstone in a limestone county, but on account of the low grade and distance from a railway is not worked. The Schmölnitz property has an area of $117\frac{1}{2}$ acres, and has a deposit of spathic ore in crystalline schist; it is 3 to 13 feet thick, and has been proved for a mile and seven furlongs on the strike and for about 260 feet on the dip, which is 40° to 60° to the south. The ore is dense, solid, coarsely crystalline, and of exceptional purity; it contains 39 per cent. of iron and 2 per cent. of manganese. For want of proper rail communication it is not worked, but is held in reserve. The Slovinka property has hitherto been worked by others for silver and copper, and as an iron mine is not yet productive, but will be in the future. The company also own a quarry of very good limestone, only $1\frac{1}{2}$ per cent. insoluble in acid, which, with the aid of 80 workers, produces about 69,500 tons of limestone and 9900 tons of lime, to supply the company's blast-furnaces and steelworks. The property abuts on the Tiszolcz station of the State Railway, and the produce is loaded into the waggons for despatch to the various destinations.

The blast-furnace installations of this company at Nyustya

and Liker have already been alluded to. With regard to the latter, it was well represented in model at the Exhibition, but, as a subsequent visit to the district showed, actual inspection was necessary to get a correct idea of the activity of the works and of the good system of the installation and methods. I have, too, already noted the completeness of the equipment, and now illustrate (Plate VIII.) the most recent furnace, as that will demonstrate better than words the character of the means now being employed in Hungary by a private company for the production of their pig iron. Although the illustration speaks for itself, I may perhaps call attention to a few points. The diameter is at stock-line 14 feet 11 inches, at bosh 17 feet 9 inches, in the crucible 8 feet 10 inches. The depth of crucible 5 feet 11 inches, depth of bosh 13 feet 10 inches, height above bosh to mouth 39 feet 5 inches, from mouth to top of superstructure 27 feet 11 inches, from bosh to stock-line also 27 feet 11 inches. The capacity is 8427 cubic feet. The boshes are cooled and the supports iron. Coke is the fuel in this furnace.

Turning now to the iron and steel works of this company, they are supplied with pig and coal from the company's own resources, but pig is also obtained from other Gömör blast-furnaces. The Ozd works are for the manufacture of merchant iron of all patterns, rails, girders, billets, and heavy sheets of all sorts, and comprise a puddling forge, a welding mill, and a Siemens-Martin works. The puddling forge includes eleven regenerative puddling furnaces, some double, some single; the former are capable of treating 18 to 21 charges of 6 cwts. each, and the latter 6 to 8 charges of 12 cwts. each in the working day of twenty-four hours, the total capacity of the forge being 35,000 tons of puddle bar per annum. The forge is furnished with four steam-hammers and two trains of cogging rolls, one with four sets of 20-inch rolls and a 250 horse-power Collmann engine, the other with three sets of rolls and a 230 horse-power Corliss engine. The puddle bar is used partly in the adjoining welding-mill, partly at the plate-mill at Nadasd. The welding-mill has three trains of rolls, six regenerative welding-ovens, and a capacity of 30,000 tons of finished iron per annum. The one train is for bar iron, with four sets of 16½-inch rolls; the first one being three-high, and worked by a 250 horse-power

Collmann engine making 100 revolutions. The second train has one three-high 16½-inch set and five two-high 12-inch sets; the roughing rolls make 100 and the finishing 250 revolutions; a Corliss engine is used. The third train has one 16-inch set and seven three-high 11-inch sets; the roughing rolls make 100 and the finishing, according to requirements, 300 to 400 revolutions.

The steelworks have four Batho gas-furnaces; they are fed by means of a rack railway, and served by a 12-ton steam-crane and two electric cranes, one 7 the other 6 tons capacity; the output is about 50,000 tons, used partly in the mill, partly at Nadasd. The rolling-mill is furnished with two trains of reversing rolls, one two-high, the other three-high. The former have sets of 38-inch cogging and 10-inch soft and hard rolls, which require 2800 horse-power; the latter four sets of 25½-inch rolls requiring 1400 horse-power. There are also soaking pits, reheating and welding furnaces, shears, saws, &c. The engines are very interesting, but perhaps it would be too tedious to introduce further details here. I may say, however, that electric transmission is used for the live rollers as well as for working some of the cranes. The accessory departments are very complete. There are 1800 workpeople, for whom accommodation, &c., is provided as usual. The Ozd works are connected to the State railway by a normal gauge line, and to Nadasd plate-works and to the Jardanhaza coal-mines by a 10-mile metre gauge line. Nadasd works are exclusively for the production of plate, &c., of all dimensions, from $\frac{1}{16}$ to $\frac{3}{8}$ -inch in thickness, with the accessory apparatus and galvanising and tinning works. The raw material is the puddle bar and open-hearth steel from the Ozd works; whilst the coal comes from the company's mines at Jardanhaza. There are various sets of rolls for tin and galvanised plate-work, and for heavy and merchant plate-work, varying in length from 29½ inches to 44, 63, and 88½ inches. There are two Siemens regenerative furnaces and seventeen recuperative furnaces. The engines are provided with an independent central condenser. The capacity of the works is about 10,000 tons a year, 400 workpeople being employed.

The Salgo-Tarjan Steel Works.—At the time of my visit to these works, they were undergoing their annual overhauling for stock-taking and repairing purposes, and so no other work was

in progress; nevertheless I was courteously conducted by Mr. P. Tetmajer Laszlo through the works. It was an interesting sight, dismantled engines, rolls, &c., and exposed underground arrangements, but, of course, lacked the vivid activity witnessed elsewhere; it, however, gave me an opportunity of giving undivided attention to the arrangement of the works and appliances. To one side were the producers, the blowing-engines, and the house for preparing the basic linings; then came the converter-house, and alongside of it the rolling-mill, in which were arranged, transversely across the middle, the train of rolls for heavy rail and girder work, and farther along the plate rolls, with the engines; behind these were the train of light rolls for fine bar and wire bar (of $\frac{1}{2}$ -inch work), running longitudinally, whilst in front, but to one side of the plate-mill, was the light rail and section mill, which delivered the rails into the rail dressing and finishing house. At the side of this house came an axle forge, with 6 heating furnaces, 4 smithy fires, 5 steam-hammers, and an axle finishing-shop with 12 lathes and 19 other machine tools, the whole capable of turning out 30,000 pairs of axles yearly. Then came an extensive area covered by wire-drawing and nail-making machinery, which, under ordinary circumstances, must present a very animated appearance. This department includes a pickling room, and incidentally green vitriol recovery. There are 130 coarse and medium, and 50 fine wire-drawing machines, for turning out wire from $\frac{1}{8}$ to $1\frac{1}{2}$ -inch diameter. The nail department has 90 wire-nail machines, and 40 machines for other kinds of nails, and a special machine for preparing galvanised bed springs; also scouring and polishing appliances; then one 150 horse-power Collmann engine, and one 250 horse-power Hartung engine, to run these machines. In addition to all this, there are workshops for making and mending the wire and nail machinery, testing-house, packing and storing rooms. The capacity of the wire and nail department is 10,000 tons. Perhaps a word or two should be said about the equipment of the steelworks and mills, so as to more or less complete the notes on the works of this company, and give a better idea of a great Hungarian iron undertaking.

The producers, ten in number, are specially arranged with

bridge-bars and large spaces below for dealing with the large quantity of ashes. Of course, there are producers in all the other works to which I have referred. In the basic lining shop there is a shaft kiln for calcining the dolomite, a drying kiln, a mixing mill, and a mortar mill for grinding the dolomite. There are three 8-ton converters alternately put in blast two coke-fired cupolas for melting the pig, one hydraulic platform and two hydraulic ingot cranes; there are underground conveyors for taking the ingots to the soaking pits, which are heated by gas. The blowing-engine is a 780 horse-power twin engine, with steam-cylinder 31 inches, air cylinder $47\frac{1}{2}$ inches, stroke 49 inches, revolutions 35 to 40, and gives 7063 cubic feet of air at 30 lbs. pressure per minute. This basic Bessemer installation has a capacity of 70,000 tons a year.

The mill has five trains of rolls, two soaking pits and five welding furnaces, and all the necessary shears, saws pendant and otherwise, cranes, live rollers, &c. The heavy work mill consists of four sets of reversing rolls, worked by a 2000 horse-power twin engine, which also serves for the plate-mills, consisting of a set of $31\frac{1}{2}$ -inch rolls, 10 feet long, as exhibited in the Budapest Exhibition. The section mill has three sets of $23\frac{1}{2}$ -inch rolls driven by a 700 horse-power engine. The wire-bar mill, two sets of 14-inch roughing rolls, and seven sets of 10-inch finishing rolls, driven by a 750 horse-power Collmann twin engine, which also drives the light bar mill of one three-high roughing set and six finishing sets. A foundry is attached to the steelworks to supply rolls and wheels. Sixteen boilers with double steam chambers, each with 5650 square feet heating surface, furnish all the steam, which is economised by a central condenser installation connected with some of the engines; there is also a water-purifying installation. Coal is brought from the company's mines $4\frac{3}{8}$ miles away by an adhesion and rack railway; the pig comes from the Liker blast-furnaces, the works being connected by a branch to the State railway at Salgo-Tarjan station. The Salgo-Tarjan works give employment to 1500 hands.

This company produces annually, from all sources, 129,299 tons of ironstone, worth £32,325; 75,547 tons of pig, worth £58,444; 4030 tons of castings and 100,000 tons of finished goods, besides

immense quantities of coal, charcoal, and wood. The cost of production is for labour £208,583; for freight, £26,943, and in 1895, £13,333 went in rates and taxes.

This communication is already of such a length that I am going to restrict myself to only other two further examples of the Hungarian iron-mining industry; and as the first I am going to select has already been set before the public in more or less detail in the *Engineer* of July 24, 1896, I purpose making this reference as brief as possible, but shall take the opportunity of making this an example illustrative of the progress since 1882, by utilising the full data furnished by the company. The company referred to is the privileged Austria-Hungarian State Railway, who mine the Vaskö and Dognacska desposits referred to above. They had a varied and attractive display in their own pavilion in the Budapest Exhibition, which was more particularly characterised by a collection of iron and steel specimens of all grades, showing a beautiful gradation in fractures. The steel specimens included open-hearth, Bessemer, crucible, manganese, nickel-chrome, and nickel steel. The labels appended gave the composition and the test results. Some were as follows:—

Kind of Steel.	Tensile Strength, Lbs. per Sq. In.	Contraction per Cent.	Elongation per Cent.
Open-hearth	64,000	62.5	21.0
" " " "	94,850	44.6	13.8
Nickel steel (hardened) .	249,775	8.2	1.47
" " (not hardened) .	105,250	59.4	12.67

With regard to the mines, Diagram 1 shows the progress made since 1882, when Ritter von Kerpely mentioned them.

Turning now to the blast-furnaces, the progress of pig production is shown in Diagram 2. In addition to those mentioned above, there is one at Dognacska turning out 4000 tons of forge pig, whilst the output at Nemet-Bozsán is 5000 tons, part mottled, part grey pig, which go to the Resicza steelworks. At these works the molten iron runs direct from the blast-furnaces into the converters. There are two converters, which produce 30,000 tons of ingots, used exclusively for railway rails. The

open-hearth plant consisted of four 8-ton and two 15-ton open-hearth furnaces, with all necessary hydraulic cranes and other accessories. The output is here 30,000 tons of ingots. This is all being reorganised, and converters and larger hearth-

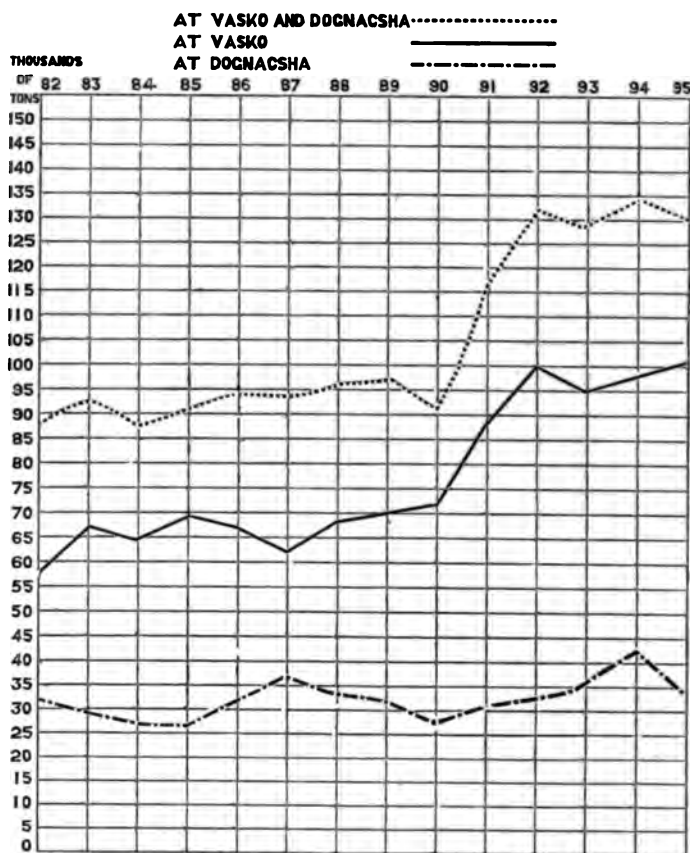
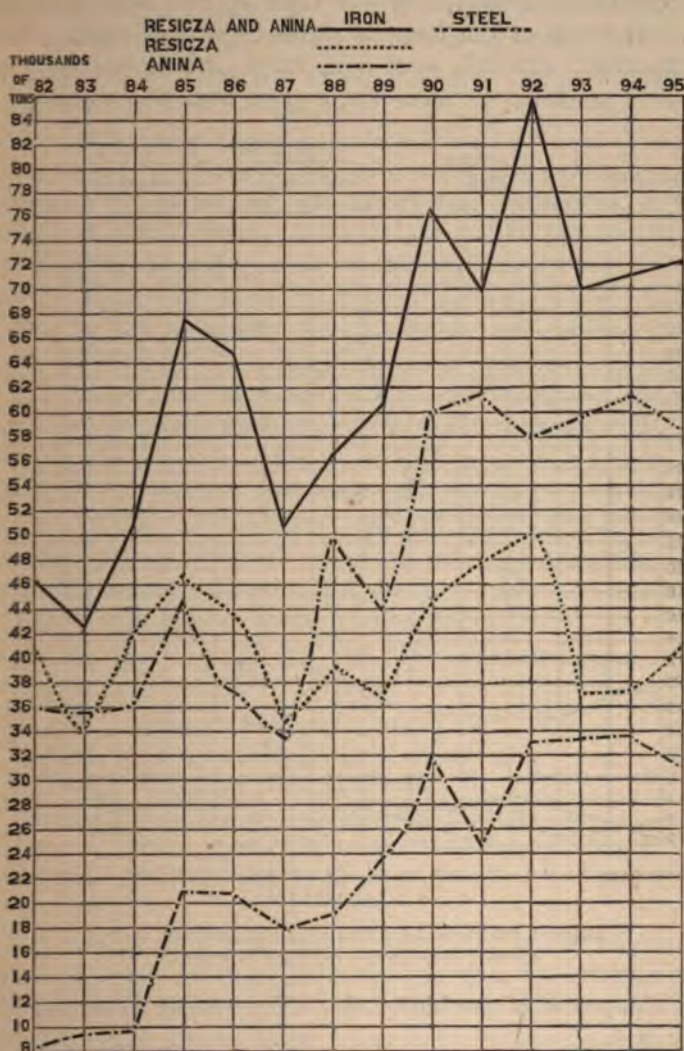


DIAGRAM 1.—Total Production of Iron Ore, 1882-1895.

furnaces are being accommodated in one building, with a long general casting pit. The output of open-hearth steel will be increased to 45,000 or 50,000 tons a year, but the Bessemer output will remain unaltered. For tool, &c., steel there is crucible steelworks giving an output of 1000 tons a year. The crucibles

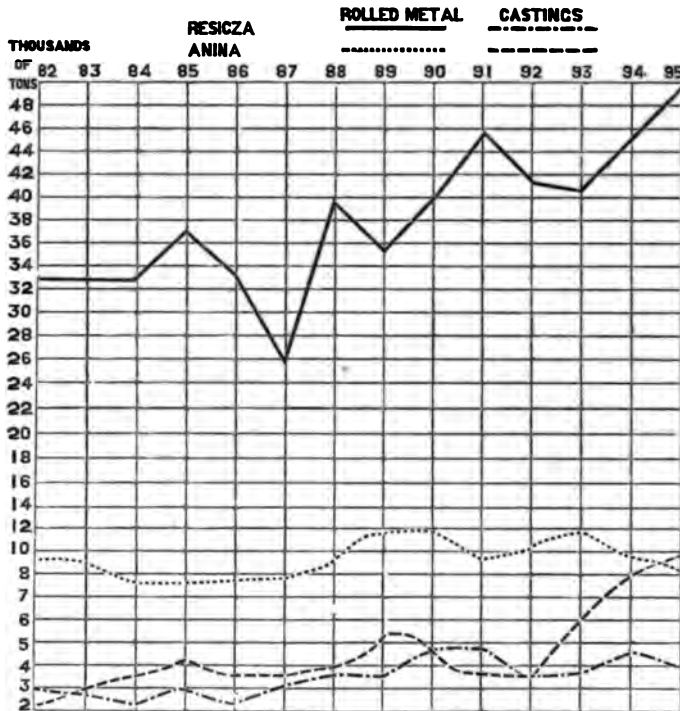
are made on the works. There is a foundry capable of turning out 3000 to 4000 tons a year, in which are placed three 8-ton



DIAGRAMS 2 and 3.—Total Production of Pig Iron and Steel at Resicza and Anina, 1882-1895.

open-hearth furnaces, giving an output of 12,000 tons. The progress in steel production at Resicza is shown in Diagram 3.

There is a puddling forge, 312 feet long and 135 feet wide, with two Pietzka revolving furnaces, two ordinary puddling furnaces, two blooming hammers, and one train of four sets of cogging rolls. The rest of the forge is utilised for steelwork. There is a fine-mill, rail-mill, plate-mill, sheet-mill, exceedingly well appointed in all ways. Moreover, a great workshop adjoins, with



DIAGRAMS 4 and 5.—Total Production of the Mills and Foundries at Resicza and Anina, 1882-1895.

Below 8, the vertical divisions are a thousand tons each;
above 8, they are two thousand tons each.

a fine equipment of machine tools. The output is set forth in Diagram 4.

The production of pig at the Anina works of this company is set forth in Diagram 2. It may be mentioned that there are fifty-two coke ovens at Anina. Anina is chiefly a great foundry, and its work is set forth in Diagram 5. There is also an

enamelling works at Anina, putting out about 300 tons of articles. The puddling forge at Anina is restricted to merchant iron and small sections, and turns out 11,000 tons, of which 800 tons are nails, screws, &c. This department was reconstructed for this purpose in 1888, and the production since then is shown in Diagram 4.

The Union Company had a pavilion of their own, and exhibited chiefly plates, sheets, and bars, tin, terne and galvanised plate, and excellent test-pieces, including circular plates over $6\frac{1}{2}$ inches diameter by $\frac{1}{8}$ -inch thick, $\frac{1}{16}$ inch thick and $4\frac{1}{4}$ feet by $13\frac{1}{8}$ feet, and sheets $\frac{1}{16}$ inch thick and $3\frac{1}{4}$ feet by $6\frac{1}{2}$ feet, and $5\frac{1}{4}$ feet by $13\frac{1}{8}$ feet, $\frac{1}{32}$ inch thick and $6\frac{1}{2}$ feet by $15\frac{3}{4}$ feet. Their works are situated $1\frac{1}{4}$ mile from the town of Zolyom, in the county of Sohl, at the junction of the rivers Garam and Szalatna, and are connected to the State Railway by a siding; they were started in 1871, mainly for the production of tin, terne, and galvanised plate. The situation was favourable for water-power, for fuel, both wood and coal, for getting good iron ore, for easy distribution of produce, and for an abundant and good supply of labour. The undertaking thrived considerably, and extended operations to the production of ordinary plate and sheet iron and steel, and at the present time has the following equipment:—

Furnaces.

- One small Bessemer plant.
- Two basic open-hearth furnaces.
- Two double puddling furnaces.
- Three reheating furnaces with Siemens firing.
- Eight reheating furnaces with Bicheroux firing.
- Thirteen heating and plate furnaces.

The rolling plant includes numerous trains for all sorts of work—two plate-mills, a billet and bar mill, a combined heavy and light bar fashioning mill, a mill for thick sheets and two mills for thin sheets, some being three-high and reversible. There are, too, all accessory appliances, including pickling, turning, leading and galvanising plant.

Power is furnished by four turbines, which supply 600 horse-power, whilst 1200 horse-power is supplied by steam-engines,

horizontal, compound, and tandem, and nineteen boilers, with a total heating surface of 16,150 square feet. The water for power is brought by two canals, one $1\frac{1}{2}$ mile long, $34\frac{1}{2}$ feet wide, and 6 feet deep, the other about 460 yards long.

With this equipment the works can put out 14,000 tons of sheets yearly, from $\frac{1}{16}$ to 2 inches in thickness, and up to $39\frac{1}{2}$ feet long and 7 feet wide; the thin sheets being further treated. In addition, all sorts of rolled work is turned out up to 5-inch square section, the capacity in this direction being calculated at 15,000 to 18,000 tons a year.

The iron used is the best Hungarian charcoal pig, other materials being also for the most part Hungarian; the machinery being almost entirely of home manufacture.

There are employed at the works nine officials and 800 work-people, most of whom live in houses provided by the company. A doctor is attached to the works, and there are sickness, accident, life, and old age assurance funds, which are entirely or partially supported by the company. Telegraphic and telephonic communication is established to the railway station, the fire stations and throughout the works, which cover an area of five acres.

The company own a coal property in Sohl county with two seams, one of lignite and one of brown coal, and iron ore mines and quarries in Zips, giving occupation to two officials and eighty or ninety workpeople, who share in all the benefits accorded to those employed at the works.

It was not, however, left to Hungary alone to distinguish herself as an iron-producing country, for both Croatia and Slavonia, and Bosnia and the Herzegovina demonstrated that they too could contribute their quota to the world's supply of this useful metal.

In a corner of the Croatian and Slavonian pavilion there was an interesting exhibit of iron ore, limestone, charcoal, moulding sand, pig iron, castings, and other objects, besides drawings of mines and works; so similar in quality was the pig and castings, &c., to those in the other parts of the Exhibition, that I was at first inclined to think that they were identical, but closer inspection revealed differences, and further inquiry elicited a certain amount of information relating to the iron industry of Croatia

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and Slavonia, which showed that these countries boast of some deposits of excellent spathic, red and brown iron ore. They also have an abundance of beech wood, as well as both lignite and brown coal; means of transport, however, are very indifferent, so that the utilisation of these inheritances is considerably limited, and only dates back ten years or so, or to the period when railways were introduced into the country. It is not astonishing to find, therefore, that the iron industry is practically restricted to the vicinity of the capital, Agram, although in other districts there are deposits that, under the existing circumstances, it is not worth while proving. Hence it is that, in spite of the good quality of the iron, the industry is restricted, but, nevertheless, is showing progress, as the following data will indicate:—

	1885.	1894.
Average of iron properties	2,642	2,825
Average of coal properties	25,415	29,780
(a) Output of iron ore tons	9,644	22,578
(b) Output of pig iron "	2,978	6,741
(c) Output of castings (direct) "	15	20½
Value of (a) in £	3,634½	4,712½
Value of (b) „	9,927½	19,378½
Value of (c) „	141½	204

The pig and castings are produced only in Agram, but part of the iron ore, 15,474 tons, comes from the neighbouring county of Modrus Rieka. There were in 1894 three blast-furnaces, of which two were in blast.

Bosnia and the Herzegovina made a more ambitious display than Croatia and Slavonia, setting forth in photographs their blast-furnaces, blowing-engines, cupolas and foundry, tube foundry, workshops, dwellings and offices, the Vares works generally, and the mines, open-cast and underground. Then there were specimens of ores and materials, and maps and statistical diagrams. Manganese and chromium ores were also exhibited. It must be remembered that in the olden times much mining was carried on in this country, but that during the Turkish occupation mining work ceased, so that all enterprise is of recent introduction, and dates back to about 1881, when the geological survey was made

by the Austria-Hungarian authorities, and now Bosnia boasts of State salt mines, coal-pits and washeries, of an iron company at Vares, and of a mining company, the latter working copper mines and works, manganese mine and dressing-floors, chromium mine and dressing-floor, and a fahlore deposit. To the other company is due the display just mentioned, but it is only within the last few years that the stage indicated has been attained. In 1890 the first modern blast-furnace was erected, with an annual capacity of 4000 to 5000 tons, and only in 1895 was the second one erected, raising the productive capacity to 10,000 tons of pig and castings; before the introduction of a blast-furnace, the output was about 130 to 150 tons. A foundry is connected with the blast-furnaces, and a rolling-mill is situated at Zenica; the ironworks being connected with the State railway by a siding 15 miles long. The mines at Przici are connected to the works by an incline tramway 690 yards long, and a rope railway $2\frac{1}{2}$ miles long; the output from the mines amounts to 100,000 tons, and serves, with the works, not only to supply the Bosnian requirements, but also for a profitable export to Hungary. The mines and works give employment to 450 people, who, as is usual on the Continent, are housed, &c., on the company's estate. It may be added that the industry is a growing one. The power is supplied by two 15 horse-power steam-engines, a 25 horse-power turbine, and four water-wheels, which combined give 60 horse-power; the two blowing-engines are together 200 horse-power. The photographs show that there are all the accessories—lifts, inclines, fans, crushers, workshops, &c.

It has been my intention to set before the members of this Institute such an account of the iron industry of Hungary as will render the present position of that industry familiar to them, and will show them to what extent this position is due to natural advantages, and what extent to human enterprise and energy, and more particularly to what extent the latter is exerted by the State, and by private adventure. Moreover, to indicate the progress that has been made since 1882, and in what manner and direction this progress has been effected. We find it signalised by improved appliances, by improved method and improved organisation; and those who know the Hungarians will be convinced, as I am, that they will continue constantly

either to improve methods, &c., themselves, or test and adopt improvements due to others.

TABLE I.—*Data Relating to Hungarian Blast-Furnaces.*

Locality.	Height.	Diameter at Boshes.	Diameter at Crucible.	Diameter at Throat.	Capa- city.	Annual Pro- duction.	Fuel.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Cub. Ft.	Tons.	
Libet . . .	41 4	10 6	3 0	6 0	1,896	1,600	.....
Govaadia . .	36 0	8 3	5 4	5 7	1,589	8,265	Beech charcoal.
Vajda Hungad	65 8	18 8	7 3	15 1	10,170	40,000	Coke.
" "	...	...	See Fig.		...	...	Charcoal.
Kalan . . .	40 0	14 6	4 0	11 9	4,132	10,000	Coke or charcoal.
Roschitza . .	55 9	...	...	...	4,520	11,500	Charcoal.
" "	65 6	...	...	...	9,781	22,000	Coke.
Bogdan . . .	44 0	11 5	4 6	8 4	2,422	4,820	.....
Anina . . .	62 4	15 9	6 6	8 9	...	17,000	Coke and coal.
" "	62 4	15 9	6 6	8 9	...	17,000	Charcoal and coal.
Liker . . .	...	17 9	8 10	14 11	8,427	...	Coke.
Tisolecz . .	43 8	12 2	4 2	9 2	3,172	3,930	Charcoal.
" "	40 10	13 6	4 8	8 9	3,531	...	Coke and charcoal.

VISITS AND EXCURSIONS AT THE CARDIFF MEETING.

A VERY full programme of visits and excursions was arranged for the Cardiff Meeting of the Iron and Steel Institute. A thoroughly representative Reception Committee was formed, with Sir William Thomas Lewis, Bart., *Vice-President*, as Chairman; Mr. William Williams, of the National Provincial Bank, as Treasurer; and Mr. T. Hurry Riches, M. Inst. C.E., of the Taff Vale Railway, as Honorary Secretary. There was a very large attendance of members and of ladies accompanying them.

The proceedings commenced on Tuesday, August 3, with a meeting of the Council at the Town Hall, Cardiff, where the members of Council were received and welcomed by the Mayor of Cardiff, Sir William Lewis (Chairman), and the members of the Reception Committee. This was followed by the reception of the members of the Institute by the Mayor, Sir William Lewis (Chairman), and the members of the Reception Committee, in the Lecture Theatre of the South Wales Institute of Engineers, after which the business of the meeting commenced by the reading and discussion of papers. The meeting adjourned at one o'clock for luncheon at the Park Hall, by invitation of the Monmouthshire and South Wales Coal Owners' Association, of which Colonel J. Williams is Chairman. At 2.45 p.m. a special train left the Rhymney Station by invitation of the Bute Docks Company and the Dowlais Iron Company, to convey the members to view the Bute Docks, the Cardiff Dowlais Works, and other undertakings near the Docks. In the evening a *conversazione* and reception was given by the Mayor and Mayoress of Cardiff, which was very largely attended. The fine building of the New Free Library and Museum had been beautifully decorated, and arrangements had been made for dancing, which was largely indulged in; an open-air promenade on the roof of the building had been provided, and as the weather was intensely hot, this was much appreciated by the numerous visitors. The function was altogether a great success.

The morning of Wednesday, August 4, was devoted to the reading and discussion of papers, after which an adjournment was made for luncheon at the Park Hall, by invitation of the President of the Cardiff Chamber of Commerce, the Right Hon. Lord Windsor, Lord-Lieutenant of Glamorganshire. In the afternoon a special train left the Queen Street Station, by invitation of the Taff Vale Railway Company, to visit Penarth Docks. In the evening the members were entertained to a sumptuous banquet in the Park Hall by the Taff Vale Railway Company. At 10 p.m. a ball was given by the Marchioness of Bute in the Exhibition Buildings, to which were invited some thousands of the leading people in the district, in addition to the members of the Institute and the ladies accompanying them. The function was a most brilliant one, the superb decorations, and the magnificent arrangements made to ensure its success, calling forth the unstinted admiration of the several thousand guests, who were received on entering the building by the Marquis and Marchioness of Bute, supported by the Mayor of Cardiff and the Town Clerk.

On Thursday morning, August 5, alternative visits to the Dowlais Iron Works and the Cyfarthfa Iron Works were arranged. The members were conveyed by special trains kindly provided by the Rhymney Railway Company and by the Taff Vale Railway Company. After inspecting the works the party were entertained to luncheon, the Right Honourable Lord Wimborne presiding. In response to the toast of the "Iron and Steel Institute," Mr. Edward P. Martin, the President, said that within two miles and a half of the hall in which they were assembled they had the home of the iron and steel industry of that district, namely, Dowlais, Penydarren, Plymouth, and Cyfarthfa, while almost within sight they had Aberdare, Aberaman, and Hirwain, the light of whose fires lit up the whole valley of the Cynon. The works in that valley had for many years past been dependent for coal upon the Manor of Senghenydd, owned by the Marquis of Bute. That manor was worked for "sea-coal" as far back as 1216, and the first lease granted was to Philip Williams, for 10s. per annum. Lord Windsor, a predecessor of the Marquis of Bute, granted a lease to Mr. William Morgan, an ancestor of Lord Tredegar, for £20 per annum, and in 1848 a lease was granted to Mr. Lewis, an ancestor of Mr. G. T. Clark, for £26 per annum. In 1757 Mr. Lewis built the first furnace at Dowlais, and in a short time came the advent of the Guest family, the late Sir John Guest being born at Dowlais in 1785. When he died the Dowlais Iron Works was the largest in the world, and he was the sole

owner of it. Mr. Jeremiah Humphrey was the first maker of refined iron, and his process probably gave the first hint to Bessemer. It was owing to a dispute between Humphrey and the Crawshays that Trevethick ran, in front of the hall in which they were assembled that day, the first locomotive ever run on wheels in this country. Referring to the Workmen's Compensation Bill, he said most men would accept the principle of the Bill, but as it stood at present, instead of associating workmen and employers, and welding their interests together, it would tend to divide them more and more. In these days they heard much of the unearned increment, but when they had men like the Marquis of Bute, Lord Wimborne, and the Messrs. Crawshay investing their money for the benefit of tens of thousands of workmen, even Socialists would admit that they were doing their duty. The Dowlais Iron Company alone spent annually half a million in wages, and Lord Wimborne himself had to find a larger amount of capital than that to carry on the works successfully.

In the evening a very large number of guests were invited by the Reception Committee to meet the members of the Institute, and the ladies accompanying them, at a promenade concert in the Park Hall and grounds, which were beautifully illuminated. The programme of music which was provided was very highly appreciated and greatly enjoyed. The concert was followed by a dance, and this brought to an end a most enjoyable and in every way successful day.

On Friday morning, August 6, a special train, by invitation of the Great Western Railway Company, conveyed the members and a large number of other guests to Newport, where they were received by the Harbour Commissioners and the Mayor of Newport, and escorted to a steamer which was in readiness to take the party to the Docks. They were shown over the Alexandra and other docks, the whole of which are the property of Lord Tredegar and Sir George Elliot. The principal exports of the Alexandra Docks are coal and steel; the imports are iron ore, pig iron, timber, pitwood, and sleepers. The coal and coke shipped here in 1876 was somewhat less than half a million tons; in 1896 it was 3,275,512 tons, whilst the total exports in 1896 amounted to 3,563,698 tons. The number of vessels entering the docks in 1896 was 1888, of 1,665,933 net register tonnage. The shipments for the first half of 1897 were as follow:—Coal and coke, 1,695,445 tons; iron and steel, 47,718 tons. The imports during the same period were: Iron ore, 55,654 tons; pig iron, 2129 tons; pitwood, 28,360 tons; timber and deal, 18,036 tons. The Newport Dock and Railway Company dispensed

their hospitality to the party, who were afterwards taken in shore close by the Bute and Penarth Docks on their way to the Barry Docks. Luncheon, by kind invitation of the Chairman and Directors of the Barry Railway Company, was served on the platform of Barry Island Station, which was tastefully decorated for the occasion. After the toast of the Queen, Lord Windsor proposed the health of the President of the Institute, and Mr. Martin replied. The visitors were afterwards shown in Barry Dock the second largest cargo steamer in the world, over 10,000 tons dead weight. The width of the entrance channel of Barry Dock between the breakwater heads is 350 feet, and the length of that channel is 1500 feet. The width of gates opening on the basin, with an area of 7 acres, and on the Dock (No. 1) with an area of 73 acres, is 80 feet, and the gates are worked by hydraulic cylinders. A deep lock with 13 feet 7 inches of water on the cill at low water of spring tides has now been completed. There are twenty-five staiths or tips for the shipment of coal, viz., twenty-one fixed, three movable, and one traversing. There are also thirty-one cranes of various kinds provided for the discharge of imports, &c.

At 5 p.m. a special train left Barry Dock for Penarth, by invitation of the Reception Committee, who entertained the party to tea in the Penarth Gardens. After inspecting the Barry Docks some members of the party went for a short cruise in the s.s. *Britannia*, by invitation of the Newport Harbour Commissioners. Invitations were also received to visit the Ebbw Vale Works, North's Navigation, the Dowlais Iron Company's new colliery at Abercynon, and other large collieries and works in the district, but the time available being so limited, it was found impossible to accept these hospitable invitations. Every facility was accorded by the Great Western Railway Company, the Taff Vale Railway Company, and the Rhymney Railway Company, to all of whom the grateful thanks of the members are due for the numerous free special trains they so generously provided.

LADIES' EXCURSIONS.

On Tuesday, August 3, the ladies were conveyed by brakes to Castle Coch, and after inspecting the Castle and the Vineyard, drove in three parties to St. Fagan's, where Mrs. Forrest entertained one party to afternoon tea; to Tynant, where the second party was entertained to afternoon tea by Mrs. Henry Lewis; to Llandaff, where the third party was entertained by Mrs. John Gunn. On Wednesday, August 4, a

special train, kindly provided by the Rhymney Railway Company, conveyed the party to Caerphilly, where the Castle was visited. The party were entertained to tea in the old banqueting hall of the Castle by the kindness of the Local Reception Committee. On Thursday, August 1st, Cardiff Castle was graciously thrown open by the Marchioness of Eglborough for the lady visitors from 3 to 6 P.M.

NOTES ON WORKS VISITED.

DOWLAIS WORKS.

Eleven Blast-Furnaces (six working and five idle).

No. of Furnace.	Height of Furnace.	Diameter of Bosh.	Size of Hearth.		No. and Type of Stoves.
			Ft.	In.	
1	60	18 6	9 6	diam. × 5 0	3 Cowper stoves.
3	70	18 6	9 6	„ × 7 0	3 „
9	60	17 6	7 6	„ × 5 0	3 Whitwell „
10	65	17 6	10 0	„ × 7 0	5 pipe „
11	80	18 6	9 6	„ × 7 6	3 Cowper „
19	60	18 0	9 6	„ × 6 4	4 Whitwell „

Nos. 8, 14, 15, 16, and 18 not working.

Four Blast-Engines.

No. of Engine.	Steam-Cylinder.		Blowing Cylinder.		Type.
	In.	Ft. In.	Ft.	Ft. In.	
1	55 diam.	× 13 0	12 × 12	0	Beam.
2	60	„ × 10 0	11 × 8	0	„
3	60	„ × 9 9	11 × 7	9	„
8	51	„ × 9 0	9 × 9	0	Horizontal.

Coal-Washing Machine.—Coppée and Luhrig's patent, designed to wash 1000 tons of coal per day. The coal is classified by screens grading boxes into various sizes, and each size washed separately. The fine coal from 0 inch to $\frac{3}{8}$ inch is washed in sixteen felspar bashes, and the coal above $\frac{3}{8}$ inch is washed in ten ordinary bashes. The coal is of various qualities, bituminous and steam, which are mixed in various proportions according to the quality of coke required.

Coke Ovens.—224 Coppée type and 130 Welsh ovens.

Cupolas at Cast-House.—Three cupolas for melting iron for steel-works, 10 feet diameter of casing, and six tuyeres.

Bessemer.—New Bessemer pit, having two converters of 15 tons each capacity. Old Bessemer, having four converters, each of 10 tons capacity.

Bessemer Blowing-Engines.

Type of Engine.	Steam-Cylinder.		Blowing-Cylinders.	
	In.	Ft.	In.	Ft.
Vertical	48	× 5	54	× 5
Horizontal	36	× 5	48	× 5
Beam	36½	× 7	48	× 7

Siemens.—Two furnaces of 25 tons each capacity, and six furnaces of 12 tons each capacity.

Cogging Mills A, B, and C.

Cog- ging.	Engines.					Centres of Mill.		Length of Roll.
	Cylinder Diam.	Stroke.	Pres- sure.	Horse- Power.	Geared.			
						In.	Ft.	
A	36	4	60	1500	3 to 1	37½	7	For Tin Bar Mill. In course of alteration. For Goat Mills.
B	36	4	80	1500	3½ to 1	37	7	
C	45	4	80	2500	2 to 1	37½	8	

Rolling Mills at Old Works.

	Rolling.	Type.	Engine.				Centres of Mill.
			Cylinder.	Stroke.	Pressure.	Horse-Power.	
Goat Mill, right	Rails . . .	2-high reversing . .	Ft. 48	Ft. In. 4 6	Lbs. 80	3,000	In. 25
Goat Mill, left	{ Rails and sleepers }	2-high reversing . .	54	5 0	80	4,000	28
Tin Bar Mill .	{ Tin bar and billets }	3-high non-reversing	42	4 0	80	1,200	23
Big Mill. . .	{ Light rails, billets, &c. }	2-high non-reversing	40	8 0	60	400	20

Rolling Mills, &c., at Ifor Works.—One forge with nineteen puddling furnaces. One light plate mill, 22-inch centres, 5 feet 10 inches roll. Two 12-inch bar mills. One 8-inch bar mill.

Rail Finishing Department and Electrical Plant.—All the straightening, drilling, ending machines, cold saws, &c., are worked by electrical power, and the lighting of this department is done with twenty-four arc lamps. The generating station for this consists of one compound engine, 13 inches and 23 inches by 2 feet stroke. Working pressure, 140 lbs. The dynamo will generate 150 horse-power at 230 volts.

The electrical power plant consists of one 10 horse-power, six 8 horse-power, three $6\frac{1}{2}$ horse-power, fourteen 5 horse-power, one $3\frac{1}{2}$ horse-power, and one 2 horse-power motors.

DOWLAIS-CARDIFF WORKS.

Blast-Engines.—Four compound condensing blast-engines. High-pressure steam-cylinders, 36 inches diameter by 60 inches stroke. Low-pressure steam-cylinders, three are 62 inches and one 64 inches diameter by 60 inches stroke. Blast-cylinder, 88 inches diameter by 60 inches stroke. Each engine can blow 25,000 cubic feet a minute, and deliver blast at a pressure of from $4\frac{1}{2}$ lbs. to 10 lbs. per square inch. Each engine, with a boiler pressure of 100 lbs., develops about 1200 horse-power.

Pump-House.—Seven compound condensing pumping engines, each having a capacity of 400 gallons per minute. Two compound condensing hoist pumps, with a capacity of 1500 gallons per minute. Three compound condensing boiler-feed pumps, working to a boiler pressure of 110 lbs. per square inch.

Hydraulic and Electric Light House.—One tandem compound condensing hydraulic pumping engine, having a capacity of 160 gallons per minute. One compound condensing hydraulic engine, delivering 90 gallons per minute. Two compound condensing hydraulic engines, each delivering 100 gallons per minute. The hydraulic pressure is 750 lbs. per square inch. There are also two tandem compound engines, each indicating 80 horse-power, giving electric light and power. The power of each dynamo is 230 amperes at 230 volts.

Blast Engine-House.—146 feet by 32 feet by 60 feet high. Capacity of top tank for tuyeres, 178,000 gallons. Capacity of tank on hydraulic engine-house, 90,000 gallons. Capacity of bottom tanks, 120,000 gallons.

Boilers.—Twelve steel boilers, 8 feet 6 inches diameter, 30 feet long, and about 250 horse-power each.

Boiler Chimney.—Height, 240 feet from Moor's level. Height, 278 feet from bottom of foundations. Inside diameter at top, 13 feet 6 inches. Capable of working twenty-four boilers.

Blast-Furnaces.—Four blast-furnaces, two of which are working, and two are being re-lined. Height of furnace, 75 feet. Diameter of boshes, 20 feet. Diameter of hearths, 10 feet. Each furnace has eight tuyeres.

Stoves.—Eleven hot-blast stoves. Height, 68 feet. Diameter, 24 feet. Heating surface, 47,500 superficial feet. Gantry lift, 58 feet. Gantry drop, 50 feet. Length of gantry, 652 feet.

Bunkers.—One coke bunker for each furnace, capacity 1250 tons. Three ore bunkers for each furnace, capacity 2600 tons. One limestone bunker for each furnace, capacity 850 tons.

There are two gantries over the pig beds for steam travellers to carry the cold pig iron in the comb to the hydraulic pig-breakers, where the pigs and sows are broken and loaded direct into trucks; each pig-breaker is capable of breaking 80 tons of pig iron per hour. The furnaces, blast-engine house, and gantries are all on piles varying from 38 feet to 24 feet long. The total number of piles is about 1800, and the quantity of timber used in them is about 80,000 cubic feet. The hearths of the furnaces are 22 feet above grass level, and the ordinary rail level of the works is 12 feet above the grass. The quantity of ballast and filling already tipped is about 1,000,000 cubic yards. By means of a subway there is an independent railway connection from the works to the wharf on the Roath Dock, where seven hydraulic cranes, six capable of lifting 35 to 40 cwt., and one capable of lifting 7 tons, are employed unloading and loading plates, ore, &c.

Steel Plant.—Consists of six Siemens melting furnaces, 3 of 40 tons and 3 of 30 tons. Each furnace has its own chimney. The gas is supplied by fourteen Ingham's 10-cwt. gas-producers with mechanical stokers. Over the furnaces there is a 30-ton travelling crane for handling molten iron, and loading material, and charging heavy scrap. A 15-ton crane transfers the ingots from the casting pit into the vertical gas furnaces. Another crane raises the ingot from the heating furnaces for the slabbing mill. The ingots average from 5 to 7 tons each.

Slabbing Mill.—The rolls are 36 inches in diameter, and slabs can be edged up to 42 inches wide. The engines are 48 inches in diameter and 60-inch stroke, geared 2 to 1. The shear will cut slabs 40 inches by 10 inches. There is a 35-ton square shaft traveller over this mill. The slabs are conveyed from the slabbing mill to the reheating furnaces, and are charged and drawn by a hydraulic radial mechanical charger.

Plate Mill.—The rolls are 32 inches in diameter and 9 feet long. The engines are 54 inches in diameter, 60-inch stroke, and geared 2 to 1. (A mill with 15 feet rolls is designed for the other side.) There is a

50-ton square shaft traveller over the plate-mill, and a quick-speed electrical traveller over the plate-mill bank. The loading of the plates will be carried out by an electric traveller in course of erection. No. 1 plate-shear will cut plates up to $1\frac{1}{4}$ inches thick, and No. 2 shear plates up to 2 inches thick. The shear-blades are on the same level as the mill-floor, so the plates are sheared without being lifted.

Test-House.—A machine for preparing test-pieces is driven by an electric motor. The tensile testing machine will test up to 100 tons, and there is a hydraulic machine for “bending” tests.

DOWLAIS-CARDIFF COLLIERY.

This colliery is situated at Abercynon, upon the Taff Vale Railway, about 15 miles north of Cardiff.

Two pits have been sunk 153 feet apart, each 20 feet in diameter and 740 yards deep. Several seams of coal of excellent quality were passed through, the two seams opened upon being from 6 to 7 feet each thick. The colliery has only recently been opened out.

The present output is about 650 tons of coal per day, which will probably be increased to 2000 tons per day when the pits are fully developed.

North Pit Winding Engine.—Cylinders 42 inches in diameter. Stroke 7 feet. Conical drum, large diameter 32 feet, small diameter 17 feet.

South Pit Winding Engine.—Cylinders 36 inches in diameter by 6 feet stroke. Drum, plain cylindrical, 17 feet in diameter. The pithead framings are each 72 feet from the landing to the centre of the pithead pulleys. The pulleys are 18 feet in diameter. Cages 14 feet 6 inches long by 4 feet 6 inches wide, weighing five tons each, and carrying two trams on single deck tandem fashion. The carrying capacity of the trams is 2 tons each, with a gauge 3 feet 2 inches.

Ventilating Fan, Schiele Type.—21 feet in diameter, driven by a compound condensing engine. High-pressure cylinder 22 inches in diameter, low-pressure cylinder 36 inches in diameter. Stroke 4 feet 6 inches. Fly pulley 20 feet in diameter. Pulley on fan shaft 8 feet 6 inches in diameter. Belt three-ply leather 3 feet 6 inches wide. There is also an auxiliary non-condensing engine, cylinder 36 inches in diameter, stroke 4 feet 6 inches.

Main Pumping Engine.—This is of the Hawthorn-Davey type, with the two rods balancing each other. High-pressure cylinder, 45 inches

diameter. Low-pressure cylinder, 78 inches diameter. Stroke, 10 feet. The whole of the water is pumped from a depth of 450 yards in three lifts. The top lift, 150 yards high, has two plungers, each 16 inches diameter, stroke 10 feet. The rising main is 14 inches diameter. The capacity of this pump is 75,000 gallons per hour. The second lift, 180 yards, has two plungers each 14 inches diameter, stroke 10 feet. Rising main, 12 inches diameter. Capacity of pump, 60,000 gallons per hour. The third lift, 115 yards high, has two plungers, each 10 inches diameter, stroke 10 feet. Rising main, 9 inches diameter. Capacity, 45,000 gallons per hour. The pump valve boxes, &c., are in each case placed in headings off the side of the pit. At each pumping station auxiliary direct-acting steam-pumps are erected, capable of dealing with the whole of the water in the event of the main pump stopping. The top pump has a rising main of 10 inches, the second of 9 inches, and the third of 8 inches, all independent of the main pumps. These pumps are supplied with steam from the surface by a 10-inch main, which is carried to the bottom of the pits for hauling as well as pumping purposes.

Air Compressors.—Built by Walker Brothers, Wigan, and driven by a compound condensing steam-engine. The steam-cylinders are—high-pressure cylinder, 28 inches diameter; low-pressure cylinder, 48 inches diameter; stroke of 5 feet. The air cylinders are also compound, with a low-pressure cylinder, 42 inches diameter; high-pressure cylinder, 27 inches diameter, with 5 feet stroke. Another similar engine is now being erected. A 12-inch main conveys the air through the south pit to the mine.

Boilers.—There are ten Lancashire boilers, each 30 feet long by 8 feet 6 inches diameter. The furnace flues are 3 feet 6 inches diameter, and are fitted with water-circulating tubes. Steam pressure, 100 lbs. per square inch.

Screens.—There are two revolving tipplers, with screens, picking bands, and creepers. The picking bands are 45 feet each long and 5 feet wide, driven by a pair of non-condensing engines. Cylinders 14 inches diameter and 22 inches stroke.

The Lamp-Room is fitted for dealing with upwards of 2000 safety lamps. The type of lamp used is Thomas's Cambrian Bonnetted Clanny, with lead locks. For damping dust in the mine, water is taken to within a few yards of the faces by pipes from feeders in the pits under a pressure of upwards of 300 lbs. to the square inch. It is intended to use Messrs. Martin & Turnbull's system of damping

dust by compressed air and water. The arches of the bottom of the north pit will be 23 feet diameter in the clear, and in the south pit 20 feet diameter in the clear. The side walls are 6 feet thick and the arch rings 4 feet thick, all built with dressed native Pennant stone.

THE BUTE DOCKS.

These docks are now famous throughout the world. They are 111 acres in extent, and will accommodate the largest vessels afloat. They are supplied with the most modern machinery for the discharging and loading of vessels, the greater portion being worked by hydraulic pressure. A working model showing the various appliances for loading and unloading was exhibited at the meeting by Sir William Lewis.

THE PENARTH DOCK.

The length of the dock is now 2900 feet, with a basin of 400 feet in length, and a water area of dock and basin of 26 acres.

MELINGRIFFITH TINPLATE WORKS.

Melingriffith Tinplate Works are situated within one mile of Llandaff Station, on the Taff Vale Railway, or four miles from Cardiff. The works consist of seven steam and four water-mills, capable of turning out 6500 boxes of 14 inches by 18 $\frac{3}{4}$ inches (124 sheets, 112 lbs.) per week, with sufficient pickling, annealing, cold rolling, and coating power to convert this quantity into finished tinplates, as well as the necessary smith's, carpenter's, and fitting shops. They are now the oldest works in the trade, and constitute one of the very few where mills are driven by water and steam-mills of 150 lbs. pressure. Weekly consumption of steel bars nearly 400 tons, and workpeople employed, 475. The works are connected with the Taff Vale Railway by means of a siding 1 $\frac{1}{2}$ miles in length, and also surrounded by the Glamorganshire Canal.

THE CYFARTHFA IRON AND STEEL WORKS.

One of the old blast-furnaces bears the date of 1765 ; also the date of 1827, when it was rebuilt. They have been almost from the commencement in the possession of the same family—the Crawshays, of Cyfarthfa Castle and of Caversham Park—under whose fostering care and indomi-

table assiduity they attained the first magnitude and eminence amongst the historical ironworks of the country—a position which they are maintaining with regard to both rail and tin bar steel amongst the foremost manufacturers of steel of the day. Amongst many other interesting facts in connection with these works, a cannon-foundry was established at Cyfarthfa about the commencement of the American war of independence, in pursuance of a contract with Government to supply powerful pieces of artillery. This business was, at the close of the war, transferred to the Carron Company in Scotland. Shortly after the battle of the Nile, Lord Nelson paid a visit to these works, which had then attained a very wide celebrity. The process of puddling was here first introduced into South Wales, being adopted by Mr. Richard Crawshaw about the year 1784, and Cyfarthfa was ever foremost in the old iron days in adopting and contriving improvements in machinery and methods of manufacture. The operations have always comprised, together with the manufacture formerly of iron and now of iron and steel, coal-mining on an extensive scale. In the year 1882 the reconstruction of the ironworks into steelworks was commenced under the superintendence of the late Mr. Edward Williams, of Middlesbrough, with whom was associated the present general manager, Mr. William Evans. Since that date the works have been largely added to and improved, until their ancient status and reputation amongst the prominent ironworks of the country have been regained in connection with the foremost and best equipped steelworks of modern construction. The Cyfarthfa Works are situated on different levels, and every advantage of gravitation has been utilised in the various processes, the first operation of the manufacture taking place on the highest ground, the products passing on from stage to stage on lower levels, until the finished steel is put into waggons on the lowest level, thus taking advantage of the natural formation of the ground to save labour. The works contain all the plant necessary for the preparation and reduction of raw material for the manufacture of iron and steel in their various forms, as well as for the manufacture of all subsidiary requirements. The only material imported is iron ore. This was formerly exclusively mined on the Cyfarthfa estate, but is now of course imported, from Spain principally. All the other requirements are obtained, prepared, and manufactured on the spot, and the plant comprises the best modern arrangements in brick-making, washing, crushing, and coking coal, blast-furnaces, Bessemer converters, and rolling-mill plant, together with all the subsidiary constructional shops and departments.

The brickworks consist of two complete plants, each capable of making both red and fire bricks on the plastic system, at the nominal rate of 20,000 bricks per day. Besides the manufacture of these bricks, tuyeres, seats, stoppers and pipes are made for use in the Bessemer department; and bricks for lining the blast-furnaces, for the Cowper stove regenerators, and for the coke ovens, all of special size or form, are also made by machinery, effecting a great saving of labour as compared with hand-making. There are six circular brick-burning kilns, each capable of burning 30,000 9-inch bricks at a time. The kilns are on the down-draught principle, and each has its own chimney, and works independently of any of the others. A rectangular kiln on the same principle has been added for burning special and fancy bricks. Suitable materials for the manufacture of excellent bricks are obtained on the property. The brickworks are lighted by electricity, and the drying stoves are heated by the exhaust steam of the brickworks engine by day, and by that from the electric light engine by night. The steam for working the engines, which together develop some 220 indicated horse-power, is generated by the waste heat from the coke ovens, conveyed to the brickworks in pipes, well covered with asbestos to prevent radiation.

The coal-washery is a very efficient plant, and gives great satisfaction. It is on the jig system. It deals easily with over 500 tons per shift, and the mixing, sizing, and washing of the coal are all that can be desired. The loss of coal due to washing is under 5 cwt. per 100 tons, while the refuse is completely eliminated, reducing the ash in the coke to a minimum. A noteworthy feature of the plant, which otherwise possesses much in common with modern coal-washing plant, is the settling chamber, which dispenses with the usual settling ponds, with their attendant trouble and expense in cleaning out, enabling the water to be used over and over again, and to this is due the very small amount of waste. The nut and pea coals on leaving the washing machines pass through a screen perforated to allow the water to escape through to the settling chamber, and are elevated to a Carr's disintegrator, where they are reduced to a powder, and fall to the foot of a second elevator, where they meet the duff coal from the settling chamber, and the whole of the coals thus reduced to the required fineness are raised to extensive storage bunkers capable of holding about 600 tons of clean coal, fitted with distributing screws, by means of which the coal is taken to whichever part requires filling.

The arrangements at the coke ovens are very complete. The ovens are of the Coppée type in two banks of ninety each, and are fed with

washed coal from the storage bunkers by means of conical dandies which pass underneath the bunker, and are filled by means of slides in the bottom of it. The dandies have sliding bottoms, through which, when open, the coal drops into the ovens. Each oven is capable of making 10 to 11 tons of coke per week. The charge of coal per oven is $2\frac{1}{2}$ tons, generally in the proportion of one-third bituminous and two-thirds steam-coal, and the time of coking is twenty-four hours. The average weekly make of the total 180 ovens is about 2000 tons. This coke is pushed out of the ovens by means of powerful steam-ram engines, carried on travelling carriages which can be brought opposite to any particular oven. The coke is conveyed to the blast-furnaces from the coke bunkers by means of dandies, several of which are placed on a low truck worked by wire ropes and a small engine, and drawn under the bunkers to be filled under sliding doors arranged for this purpose. After they are filled the truck is withdrawn and the dandies are brought back to a point level with the top of the furnaces, to which they are wheeled direct. The waste heat and gases from the ovens are utilised under ten boilers for generating steam for driving and washing, crushing, and distributing machinery at the washery and ovens, and brickworks, blast-engines at the blast-furnaces, and other contiguous machinery.

There are five blast-furnaces of modern construction and dimensions, each 70 feet high, iron cased, close topped, having the throat 12 feet, bosh 18 feet, and crucible $8\frac{1}{2}$ feet diameter. The last furnace has had its casings, &c., made larger to allow of 20 feet boshes if desirable, though at present it is lined in uniform contour with the other four. The internal capacity of each furnace is about 12,000 to 13,000 cubic feet, and the average output per furnace is 800 tons hæmatite iron per week. The tops of the old blast-furnaces are now utilised as a platform, on which the stock of iron ore, &c., is deposited from an overhead gantry. From this storage bunker the material is taken to the furnaces by two lifts, one vertical and the other on an inclined plane, actuated by winding-engines. Blast is supplied by three vertical direct-acting condensing blowing-engines, by J. C. Stevenson & Co., Preston, each having a steam-cylinder 33 inches, and a blast-cylinder 72 inches diameter, by $4\frac{1}{2}$ feet stroke; and by three vertical direct-acting condensing engines, by Davy Brothers, Sheffield, one having a steam-cylinder 44 inches, and air cylinder 96 inches, and the other two—now in course of erection—having steam-cylinders 45 inches, and air cylinders 96 inches diameter, the stroke in each case being 5 feet. The pressure

of the blast is $5\frac{1}{2}$ lbs. to 6 lbs. per square inch, and all the engines are capable of carrying a pillar of blast of 8 lbs. to 10 lbs. per square inch if desired. The tuyeres to each furnace are six in number, placed at equal distances round the crucible. The blast is heated by fifteen Cowper stoves, ranged in a row at the back of the furnaces, twelve of which are 21 feet diameter by 60 feet high, and the last three 24 feet diameter by $80\frac{1}{2}$ feet high.

There are two ranges of Lancashire steel boilers, supplying steam to the blast and other engines, making a total of eighteen boilers, the one group of boilers being each 7 feet diameter by 30 feet long, and the others being $8\frac{1}{2}$ feet by 30 feet. These are usually fired by the surplus gas from the blast-furnaces aided at times by a little coal, or they can be entirely fired by coal. Railways are arranged between the pig beds for removing the slag and for conveying molten metal to the Bessemer department. The slag falls and the tapping levels are sufficiently high above the rail level to allow of this being done. The slag is run into bogies and the metal into a ladle on a carriage, which, after receiving a quantity of molten iron from two or more furnaces, is usually run under the tapping shoot of the remelting cupolas, and after receiving a quantity of remelted iron, is run across the river Taff over an iron bridge on to the Bessemer stages, where the iron is poured into the converters for conversion into steel.

In addition to this plant of five modern furnaces there is another group of four blast-furnaces at Ynys Fach of an older type, equipped with beam blowing-engines, pipe stoves, boilers, and coke ovens, &c., complete. These furnaces are 53 feet high, with 12 feet and 13 feet boshes. These are not now in blast, but in their day were considered a very superior type of furnace, and their performance was always creditable, and they are even now available as a very respectable addition to the output of the works in case of need.

The Bessemer converters are four in number, of a nominal capacity of 10 tons. They are arranged in line, and are not under cover. There are two casting-pits 40 feet diameter, 72 feet centres, each served with a centre or casting crane, having double rams and a centre guide, and with three single-ram ingot cranes. The converter bottoms are changed by means of two hydraulic cranes, fixed on the Bessemer stages; the time occupied in changing a bottom is from twenty to thirty minutes; these cranes are also used for scrapping and for charging spiegel. The pressure of blast is 25 lbs. per square inch, and is supplied by two blowing-engines. The No. 1 Bessemer blowing-engines are by Messrs. Tannet-

Walker & Co., Leeds; they are vertical condensing, the two steam-cylinders being 42 inches diameter, air cylinders 55 inches diameter, and the stroke is 5 feet. The cylinders were formerly compounded, but have recently been equalised. The No. 2 Bessemer blowing-engines by Messrs. Daniel Adamson & Co., Dukinfield, are vertical condensing, the steam-cylinders being 40 inches diameter, the air-cylinders 54 inches diameter, and the stroke being 5 feet. These are in the same engine-house, in which are also three sets of hydraulic pumps, two by Tannett Walker & Co., and one by Davy Brothers, pumping against an accumulator weighted to give a pressure of 700 lbs. per square inch, for working the cranes and the converters. There is also one of Tannett Walker's three-cylinder blast-engines for supplying blast to the spiegel cupolas. All these engines have the Bulkley condenser attached to them, maintaining a steady vacuum, without any air pumps or moving parts, but requiring a large volume of water. On the north side of the Bessemer stage is the ganister crushing, grinding, and mixing plant; an excellent deposit of silicious stone is quarried on the spot suitable for ganister for the converter bottoms, and for making into silica brick. Adjoining is the plug shed in which the converter bottoms are made up, dried, and stocked ready for use at the converters. An overhead 6-ton travelling crane, by Booth Brothers, Rodley, takes in the whole shop and deals with the bottoms.

There are some six or seven rolling trains at Cyfarthfa, two of which, the old rail-mills called the Pandy and the Castle Mills, have been entirely reconstructed on the most modern lines, and are now called No. 1 and No. 2 steel-mills. These, together with the merchant bar and guide mills, occupy a long range of shedding of most substantial structure with dressed stone gables, adjoining the Bessemer department, which, together with the hot banks and rail sheds, cover about twelve acres of ground. No. 1 mill has been at work some twelve years, but No. 2 is now in course of erection, and as this mill will present some features which will ultimately be adopted in No. 1, a short description of this mill will largely serve for both, as the dimensions given generally apply to either. At present No. 1 mill is served by eight heating furnaces ranged in front of the Bessemer pits, from which two 4-ton ingot cranes lift the ingots on to bogies which charge the furnaces. The ingots are drawn out of the heating furnaces by four wire-ropes passing over the top and centre of the doors, worked by hydraulic pressure. Forced draught produced by steam jets is applied under the furnace grates, whereby fuel of inferior quality is used. Over each heating furnace,

supported on strong cast iron pillars and wrought iron girders, is a three-flued boiler by Davy Brothers, Sheffield. The waste heat from the furnace passes through the boiler twice, and afterwards upwards towards the chimney through a vertical feed-water heater. The boilers will be retained, but it is ultimately intended to adopt a type of vertical furnace here similar to that put down for No. 2 mill, the waste heat and gases from which will be utilised for use in the boilers.

No. 2 mill is being erected where stood the old Castle Rail Mill, and in its arrangements modern ideas and contrivances for minimising labour and increasing the output have been adopted, so far as the exigencies of existing buildings and machinery will permit, which, in some cases, require very considerable alteration and rearrangement. The rolling trains consist of a 36-inch cogging-mill, driven by a geared pair of horizontal reversing condensing engines, 42 inches diameter by 5 feet stroke, and a 27-inch roughing and finishing train, driven by a pair of horizontal reversing condensing engines, 50 inches diameter by 5 feet stroke. The cogging mill has a 6-inch lift of rolls, controlled by hydraulic balancing rams, and by a steam screwing-down gear. This makes the cogging-mill an almost universal mill, for besides supplying the rail-mill with bars of required sections, blooms, slabs, and billets of every practical size can also be turned out.

This mill is also provided with a hydraulic gear of the most approved type for turning or manipulating the ingot during its passage through the rolls. A powerful horizontal bloom shears is placed nearly half-way between the cogging-mill and the roughing-mill, and a subway is arranged for dealing with the crop ends, cobbles, &c., and a hydraulic crane also has been conveniently placed for serving this shears. The ingots are brought in from the Bessemer shop on bogies, drawn by a 3-feet gauge locomotive, and it is intended to strip the moulds in convenient contiguity to the soaking-pits.

The soaking-pits or vertical furnaces are served by cranes so arranged as to command the roads bringing in the ingots, and a line of live rollers running direct to the cogging-mill, so that the charging and drawing of the furnaces are thoroughly under control. The ingots are cogged to a bloom about 7 inches square, which, after treatment at the shears, will be long enough to roll into four, three, or two lengths of rails, either 30 feet, 40 feet, or 60 feet long, as may be required. This bloom is carried by live rollers to the roughing rolls, where, when roughed, it is turned over by means of a hydraulic apparatus to the finishing rolls, and thence to the hot saws by suitable draw-out roller gear. The required lengths

are regulated by stoppers, carried by girders spanning the hot bank. The hot bank for the new mill will be 320 feet in length, and the rails, or such other material as may be rolled, will be dealt with by skid engines, actuating skids from either end of the bank. The hot bank consists of rails, carried by cast iron standards arranged on continuous transverse bed-plates, so that the hot bank can be either narrowed or widened with great facility to suit the various lengths of bars or rails. Each standard has an arrangement for taking up the expansion of the bank caused by the hot material. The hot skid consists of twin skids, with fingers placed at a considerable distance apart, so that the pressure exerted to move the rail is sufficiently spread to prevent the latter from bending while yet hot and pliable. A single skid dealing with the cold bars, and working between the twin skids, is driven by an engine at the opposite end of the bank, and is used for shifting the bars and rails towards the straightening presses, or for stocking them. Each skid is driven by a pair of 8-inch horizontal engines and climax pulleys, arranged with pulleys at opposite ends of the banks for tightening up the ropes. The skid engines for the new bank, and for the existing bank for No. 1 mill, which is of similar construction and arrangement, are by Messrs. Davy Brothers, who also supplied the whole of the mills and mill gear in No. 1.

The engines for No. 1 mill were supplied by Messrs. Galloway, while the whole of the mills, live rollers, roller engines, saws, shears, &c., together with the powerful cogging and finishing engines for No. 2, are being supplied by Lamberton & Co., Coatbridge.

The rail finishing plant is arranged under a roof of three bays of 60 feet span by 120 feet long, and consists of straightening presses, ending machines, drills, punching and notching machine, emery wheels, and rail testing apparatus by Messrs. Joshua Buckton & Co., Leeds, who also supplied similar machines for No. 1 rail bank. These, as in No. 1 rail shed, will be driven partly by independent self-contained engines and partly by shafting and belt pulleys to be worked by a semi-portable 40 indicated horse-power Robey engine, or an equivalent engine.

Adequate lengths of rail benches will be laid down, so arranged that the finished rail will be delivered into trucks on a lower level, so that no lifting will be required, exactly similar to existing arrangements for the product of No. 1 mill. The casing of the new furnace and stoves, the new bridges, and all girders, roof trusses, and other wrought iron work have been made on the premises, and by the Company's own men.

Under contiguous shedding to No. 1 rail shed is a sleeper plant, consisting of a steam lever-shears by Davy Brothers, for cutting hot bars into suitable lengths for sleepers, and a patent heating furnace, fed by steam power, one powerful hydraulic sleeper press, and two hydraulic punching presses, all by Davy Brothers. Adjoining the No. 2 mill are the merchant bar and guide mills, driven by an oscillating non-condensing vertical engine, 34 inch cylinder by 5 feet stroke. The merchant mill has three-high roughing and two-high finishing rolls, while the guide mill has three high-roughing and three high-finishing rolls. There are four heating furnaces. In close proximity to this mill are nine lathes for roll turning, which are driven by a vertical non-condensing engine, 26 inch cylinder by 30 inch stroke, and served by a 15-ton overhead travelling crane. In the lower forge is a 16-inch forge train, worked by a water-wheel 20 feet diameter by 10 feet wide, which also works a squeezer and shears. A 17-inch bar-mill, under the same roof, is driven by a water-wheel of the same dimensions, and both trains are served by some twenty-one puddling furnaces.

In the old upper forge, which is now idle, there is a large water-wheel 36½ feet diameter by 8 feet wide, which is remarkable in that it combines in itself the features of an over-shot, breast, and under-shot wheel, as the water was applied at three different points. This is considered an excellent specimen of the engineering of its day, and has turned out enormous quantities of work. In connection with the steel-mills Nos. 1 and 2, may be mentioned that they are provided with overhead travelling cranes dominating the whole span, and providing every facility for changing rolls, and every other similar requirement.

The engineering shops consist of fully equipped foundries, pattern-shop, machining and fitting shops, boiler and smiths' shops, carpenters' and waggon-building shops, and sawmills. The foundry proper is furnished with two steam 15-ton cranes and two hand-power cranes, two cupolas, two large air-furnaces, and a roll-casting pit, in which chill and other large rolls for the works are cast. The ingot mould foundry is also completely equipped for its operations, with overhead steam travelling crane, stoves, &c., and is placed adjacent to the remelting cupolas for the Bessemer department. The pattern-shop is fitted up with steam-power turning lathes, circular and band saws, hand-power mitreing shears; and the fitting shop is adequately furnished with suitable heavy and light tools for dealing with the many requirements of the works, and there is also a large locomotive repairing shop for the fifteen locomotives required to deal with the heavy traffic. The smithy

contains twenty fires and two bolt and rivet-making olivers. The boiler-shop contains plate-heating furnaces, bending rolls, shearing and punching machines, drilling machine, &c. Beyond the fitting shop to the north is the old brickworks, now used for the manufacture of silica bricks for lining the Bessemer converters, &c. The total horse-power is 29,000.

ALEXANDRA DOCKS, NEWPORT.

At the Alexandra Docks ample accommodation is provided for vessels of the largest capacity, the dimensions of the docks being as follows:—

Description.	Dock.			Lock.		Depth of Water on Cill.	
	Deep-Water Acreage.	Length.	Width.	Length.	Width.	Spring Tides.	Neap Tides.
South Dock	20	Feet. 1500*	Feet. 550	Feet. 503½	Pt. in. 72 0	Feet. 35	Feet. 25
Alexandra Dock	28½	2500	500	350	65 0	35	25
Old Dock	11½	1753	300	220	61 0	31	20
Graving Dock	1	523	74	Entrance	49 11	20	Average
Alexandra Timber Float	10	2600	150	...	...	8	Average
Elaina Wharf	2	340	250	...	...	25	15

The principal exports of the Alexandra Docks are coal and steel; the imports are iron ore, pig iron, timber, pitwood, and sleepers. The coal and coke shipped here in 1876 was somewhat less than half a million tons; in 1896 it was 3,275,512 tons, whilst the total exports in 1896 amounted to 3,563,698 tons. The number of vessels entering the docks in 1896 was 1888, of 1,665,933 net register tonnage. The shipments for the first half of 1897 were as follows:—

	Tons.
Coal and coke	1,695,445
Iron and steel	47,718

The imports during the same period were:—

	Tons.
Iron ore	55,654
Pig iron	2,129
Pitwood	28,360
Timber and deal	18,036

* 2270 when completed.

BARRY DOCK.

The width of the entrance channel between the breakwater heads is 350 feet, and the length of that channel is 1500 feet. The width of gates opening on the basin, with an area of 7 acres, and on the dock (No. 1) with an area of 73 acres, is 80 feet, and the gates are worked by hydraulic cylinders.

A deep lock with 13 feet 7 inches of water on the cill at low water of spring tides has now been completed.

There are twenty-five staiths or tips for the shipment of coal, viz., twenty-one fixed, three movable, and one traversing. There are also thirty-one cranes of various kinds provided for the discharge of imports, &c.

	Tons.
Average shipment per week, last half-year	119,783
Largest weekly shipment.	158,631
Largest daily shipment	33,143
Largest quantity shipped in one hour at one tip	490

THE BUTE SHIPBUILDING, ENGINEERING, AND DRY DOCK CO.,
LIMITED, CARDIFF.

The above works and dry docks are situated just within the main entrance to the port, viz., Roath Basin. The docks are 600 feet long and 74 feet wide at bottom, and such large steamers as the *Knight Bachelor*, *Ranza*, and *Samoa*, which are the largest traders to the Bristol Channel, have been dry-docked in these docks. Vessels can be docked and undocked regardless of tides and without the aid of tugs, and are then in a position to proceed to either the Roath Basin, Roath Dock, or East Dock, for loading with the minimum of transporting. The dry docks are so constructed that the water can either be pumped out or run away into the Channel. The whole of the machinery is of the most modern type, thus enabling the Company to carry out repairs with economy and despatch.

THE CARDIFF CHANNEL DRY DOCKS.

The Cardiff Channel Dry Docks and Pontoon Co.'s property, situated outside the entrance to the Roath Basin, midway between Cardiff and Penarth, and adjoining the Bute Docks Co.'s large new import and export dock now under construction, is one of the features of the port of Cardiff. The dry dock, which is rapidly nearing completion, is expected to be opened during the first week in October next, and when finished,

it is computed it will be one of the finest in the United Kingdom, and replete with the most modern plant and machinery. This dock will be excelled in capacity and equipment by one or two Government docks only, which are specially constructed for accommodating battleships, &c. The position of this dock and pontoon is unique, being equally available for vessels dry docking and afterwards loading at Cardiff, Newport, Barry, or Penarth. Every possible source has been consulted to ensure the appliances of this dock being equal to modern requirements, and every provision has been made to accommodate the longest vessels which are ever likely to enter the Bristol Channel. The dock itself will be over 600 feet in length and 110 feet in breadth, and will be capable of taking in at any time four ordinary sized vessels. The pontoon has at all times been in great demand, and steamers up to 325 feet can be docked on one tide, painted and undocked on the next tide, thus ensuring to the shipowners what is required in these times, every despatch and economy in the docking and repairing of their vessels.

JUNCTION DRY DOCK, CARDIFF.

This dry dock forms a junction between the Bute East Basin and the West Bute Dock, and is easily reached by vessels from the East or West Docks, or *via* the Junction Lock from Roath Basin or Roath Dock. It is also very conveniently situated in respect of the merchants' and shipowners' offices, being only within a few hundred yards of the Cardiff Exchange, and within two minutes of the Dock's Post Office. This dry dock is 420 feet long by 77 feet wide, with an entrance at each end 50 feet wide, closed by caissons, over which at the east end the Bute Dock Railway is carried. The engineering and various workshops, stores, &c., are built round the dry dock, and there is a most complete installation of all kinds of machinery and all appliances for the purpose of executing all kinds of repairs to steamships and sailing vessels, including their machinery, hulls, or boilers. The dock is pumped out by a pair of centrifugal pumps in the course of two hours, with an auxiliary beam-engine for draining purposes.

THE NEWPORT WORKS OF MESSRS. MORDEY, CARNEY & Co., LIMITED.

The area of the works is 5 acres, comprising three dry docks and well-equipped fitting and boiler shops, shipbuilding plant, &c. The total

number of ships and steamers repaired and docked last year was 441. The firm are builders of small steam-vessels up to 600 tons, and build their own engines and boilers. They have recently built several crafts for foreign account, besides a powerful screw tug for Messrs. W. & T. Jolliffe, of Liverpool.

The works are the oldest established of their kind in Newport. During Messrs. Mordey & Carney's time considerable improvements have been made. Within the past few years they have constructed a large modern dry dock. The company are also the proprietors of the Cardiff Slipways and Central Engineering Works, Cardiff, besides a large branch establishment at Barry Dock.

THE GREAT WESTERN COLLIERY COMPANY.

The Great Western Colliery Company, Limited, have a taking of over 3000 acres of steam and house coal, situated at the southern end of the Rhondda Valley, say between the Hafod Ynysbwl and Pontypridd Stations of the Taff Vale Railway, and from which they are now working about 750,000 tons of steam-coal yearly.

At the Western Colliery, situated on the western side of the railway, they have two pits. The No. 1, or Hetty downcast shaft, is the principal one for raising coal, but a fair quantity is also brought to bank at the No. 2 upcast shaft. There is a recently erected compressed air engine for underground haulage, also 120 Coppée coke ovens.

The Tymawr Colliery is on the eastern side of the railway. The coal is raised from an old shaft which was deepened to cut the lower measures. There is here a very fine compressed air haulage plant, the steam-engines being compound condensing, with apparatus for re-cooling the condensing water.

At the Maritime Colliery, near Pontypridd, there are also a couple of pits. This colliery was only lately acquired, and is being developed chiefly with a view to the production of coking coal.

POWELL DUFFRYN STEAM-COAL CO., LIMITED.

This Company possesses a large-sized coal-washery with 160 Coppée ovens. There are two pits winding coal from 440 and 530 yards, fitted up with air-compressing plant for underground haulage, and the generality of the machinery is of the most modern type. The underground pumping-engine forces 600 gallons per minute 530 yards vertical.

NORTH'S NAVIGATION CO.'S LLYNVI COLLIERIES AND COPPÉE
WASHERY AND COKE OVENS.

The Caeran pits are situated at the north-east extremity of the Llynvi Valley, and are connected by a private line some four miles long with the Great Western Railway (Bridgend Junction), and have access over the Great Western Railway to the Bute Docks, Cardiff, with the Vale of Glamorgan Railway to Barry Dock, and with the Port Talbot new railway and docks. The depth of the shafts is 330 yards to the 6-foot seam, which is the seam now being worked. The section of coal is 5 feet 6 inches of clean coal, with an excellent roof. The permanent winding engines are fitted to the upcast shaft only as yet, and are capable of winding some 2000 tons daily. At the present time this colliery is winding some 1000 tons daily, and as the colliery develops it is intended to replace the cages by others to carry two trams. These cages are on the ground.

The workings are at present ventilated by an open-running fan, 10 feet 6 inches in diameter by 3 feet 6 inches wide, making 200 revolutions per minute, driven by a double compound single-acting high-speed Bumsted and Chandler engine. This fan will ultimately be replaced by another of larger capacity. The whole of the surface and the bottom of the shafts are lighted by electricity. The dynamo is driven by a 3-foot Pelton wheel, the head of water being 150 feet, obtained from the hills. Electrical plant is being erected for underground pumping. The whole of the coal, after being screened on the main screen, passes over picking-bands, where it is double-screened and hand-picked. This coal is known as "North's Imperial Coal."

The Coppée coking and washery plant, which is in direct communication with the private line before mentioned, consists of sixty coke ovens. A further forty ovens are in course of construction. The coke made at these ovens is manufactured from the "2½ feet" and "2 feet 9 inches," or red ash coals, obtained from the No. 9 and Maesteg Collieries, which, together with the Coegnant Steam-Coal Colliery, are also in connection with the afore-mentioned private line.

THE "WESTERN MAIL" OFFICES.

The *Western Mail* offices in St. Mary Street are built upon part of the site occupied by premises which were destroyed by fire in 1893, and are amongst the loftiest, most commodious, and best lighted newspaper

offices in the kingdom. The ground floor, which has a uniform height of nearly 21 feet, consists of a noble vestibule having a mean width of 24 feet, lined with encaustic tiles. Separated from the vestibule by a teak and plate-glass screen is the advertisement office, and at the rear of this are the stationery and typewriting departments, secretary's, cashier's, advertisement manager's, and accountant's rooms, and the clerks' office. The upper floors are approached from the vestibule by a hydraulic lift and a handsome teak staircase. The first floor is nearly 17 feet in height. Facing the street is the editor's room, behind which is the porter's office and the general manager's room. At the rear are the editorial offices and photo-etching department. The second floor also has a height of nearly 17 feet, and consists of the editor's private rooms in the front, and in the rear the stereotype foundry, linotype room, readers' room, &c. The linotype room contains fourteen machines, most of them duplex, and one headline machine, fitted with two distinct founts of matrices in each magazine. There is a second hydraulic lift at the rear of the building, intended for the conveyance of stereotype plates from the foundry to the machine-room in the basement, but also affording communication between every floor. In the basement are three powerful tubular boilers, a pair of compound engines, pumps for working the hydraulic lifts, two dynamos for supplying electric light to the buildings, and two Hoe presses. One of the latter is a double-width machine, from which can be printed a paper of any number of pages from four to sixteen, the latter at the rate of 12,000 per hour. The smaller machine will print a four-page paper at the rate of 24,000 per hour, or eight pages at the rate of 12,000 per hour.

REPORT ON THE INTERNATIONAL CONGRESS FOR THE UNIFICATION OF METHODS OF TESTING.

THE International Congresses for the unification of methods of testing were, as was pointed out by Professor G. Lunge in his report* on the Zürich Congress, called into existence by the late Professor Bauschinger, and were held at Munich, Dresden, Berlin, Vienna, and Zürich. At the last-named Congress the Congresses were consolidated into a permanent organisation termed the International Union for the Testing of Technical Materials. This Association publishes official Transactions, and its business is conducted by a council consisting of Professor von Tetmayer, of Zürich, president, Professor Bebelubski (St. Petersburg), Oberbaurath Berger (Vienna), Professor Martens (Berlin), and Baron Quinette de Richemont (Paris). The annual subscription to the Union is 4s. In order to show the interest taken by British metallurgists in the work, it was decided by the Council of the Iron and Steel Institute that it was highly desirable for each of its members to join the Association.

The first Congress held under the auspices of the Association took place at Stockholm on August 23 to 25, 1897, and Mr. R. A. Hadfield, Member of Council, and Mr. Bennett H. Brough, Secretary, were appointed to represent the Iron and Steel Institute on that occasion. The Congress was attended by 360 members, the numbers delegated from each country being as follows:—

Austria	33	Italy	6
Belgium	5	Luxemburg	1
Denmark	10	Norway	15
Germany	86	Portugal	1
England	5	Russia	33
Finland	7	Spain	9
France	43	Sweden	77
Holland	2	Switzerland	10
Hungary	14	United States	4

The chair was taken by the President, Professor von Tetmayer, and the business was conducted in the German, French, and English lan-

* *Journal of the Iron and Steel Institute*, 1895, No. II. p. 310.

guages. A welcome having been accorded to the Congress by Mr. E. von der Lancken, deputy-governor of Stockholm, the President read a report of the proceedings of the Association since the Zürich Congress. The following gentlemen were then elected Honorary Presidents of the Congress:—Mr. W. Ast (Austria), Mr. A. Greiner (Belgium), Professor H. J. Hannover (Denmark), Mr. Nyberg (Finland), Mr. T. Peters (Germany), Mr. Bennett H. Brough (England), Mr. E. Polonceau (France), Mr. H. Baucke (Holland), Mr. C. Banovits (Hungary), Mr. S. Fadda (Italy), Mr. A. Dutreux (Luxemburg), Mr. H. Krag (Norway), Mr. J. V. Mendes Guerreiro (Portugal), Professor N. Bebelubaki (Russia), Colonel A. Mayanda (Spain), Mr. R. Åkerman (Sweden), Mr. A. Schrafl (Switzerland), and Mr. G. C. Henning (United States).

The meeting was then divided into two sections, one dealing with metals and the other with stone, cement, and other building materials. In the metallurgical section the first paper read was by Mr. Axel Wahlberg (Director of the Stockholm Testing Works), on the development of testing methods in Sweden. A lecture by Mr. F. Osmond on metallography as a method of testing was warmly applauded, and the numerous lantern slides illustrating the microscopic structure of metals attracted great interest. Mr. Ast and Mr. Barba read a paper on the resolution proposed by Mr. Schrödter at the Zürich Congress, that endeavours should be made to introduce international uniform specifications of the quality, testing, and acceptance of iron and steel materials of every description. In the discussion that ensued, Mr. Schrödter pointed out that most of Mr. Ast's propositions were not in accord with the views he had in his mind when two years previously he brought forward the proposition. The field of operations had been extended in such a manner as to render it difficult to arrive at a conclusion.

Mr. E. Polonceau then submitted a report on the divergencies between the resolutions arrived at by the previous International Congresses and by the French Commission on Methods of Testing.

Professor Wedding read a report on the establishment of an international laboratory for the chemistry of iron. The aim of such a laboratory would be to compare and to fix the degree of accuracy in the analytical methods employed, and to specify those which were worthy of recommendation in cases of controversy, whether for exact assays in technical laboratories, or for daily controlling the manufacture. The laboratory would in no way be occupied with commercial and technical analyses, nor with analyses made for third parties.

Thanks to the generosity of the Swiss Government, a suitably equipped building had been provided, and the salaries of the officers had been partially covered by voluntary subscriptions promised for ten years by the leading ironworks. Although the sum promised was not yet sufficient to carry out the programme in its entirety, it was sufficient to warrant a start being made.

A detailed report of the proceedings of the Congress is published in the official organ of the Association—*Baumaterialienkunde* (Stuttgart).

It was decided that the next Congress should be held in Paris in 1900, and the following gentlemen were elected additional members of the Executive Council,—Mr. R. A. Hadfield (Great Britain), Mr. Axel Wahlberg (Sweden), and Captain O. M. Carter (United States).

OBITUARY.

GUILLERMO BOBRZYK, of Garrucha, Spain, died at Magdeburg in September 1897. He was a man of high professional standing as a mining engineer, and contributed largely to the development of the lead and iron mining industries of the provinces of Almeria, Murcia, and Granada. His interests were not confined to his professional work. He possessed great literary taste, and collected a unique library dealing with the Moorish dominion in Spain. He was elected a member of the Iron and Steel Institute in 1892.

WILLIAM DAVIES died at Sheffield on July 14, 1897. Born at Merthyr-Tydvil in 1836, he learnt the business of draughtsman and pattern-maker at the Ebbw Vale Works, where his father was employed as forge manager. On leaving the Ebbw Vale Works in 1862, his father became forge manager of the Millwall Works of Messrs. Hughes, and in 1864 Mr. Davies was appointed assistant manager, and on the death of his father he was appointed manager. After serving for a short time as manager of the Coatbridge Works of Messrs. Jackson, he became in 1871 connected with the firm of John Brown & Co., where he was identified with all the various changes in armour-plates during the past twenty-five years. He was obliged, in consequence of failing health, to retire from business, and his valuable services to the company were recognised by a substantial pension. He was elected a member of the Iron and Steel Institute in 1889.

BRUNO EHRHARDT died at Bockwa, near Zwickau, Saxony, on October 16, 1897. Born on April 11, 1836, at Oberrossau, he received his technical education at the Chemnitz and Dresden Technical Schools, and at the Freiberg School of Mines. On December 1, 1857, he received an appointment at the Königin Marienhütte at Cainsdorf, near Zwickau, at that time the only large ironworks in Saxony. At these works, to which he devoted his whole life, he rose from being foreman at the coke-ovens up all the steps of the ladder to the position of general

director of the company. At the end of 1888 he was obliged by ill-health to resign his official duties. In recognition of his great services in developing the iron trade of Saxony, the King bestowed on him the Cross of the first class of the Albrecht Order, and subsequently conferred on him the title of Bergrath. He was elected a member of the Iron and Steel Institute in 1880.

JOHN FRANCIS HALL died at Sheffield on June 3, 1897, at the age of forty-three years. After being educated at Sheffield and at Neuwied, Germany, he entered the works of Messrs. William Jessop & Sons as a pupil in 1870. He remained with that firm for twenty years. His attention was subsequently devoted to the use of steel castings as a substitute for iron in work connected with naval architecture. He was the inventor of the patent anchor which bears his name, and of various other contrivances. He was a member of the Institution of Civil Engineers, of the Institution of Mechanical Engineers, and of the Institution of Naval Architects. He was elected a member of the Iron and Steel Institute in 1878.

DAVID JONES died very suddenly, of heart disease, at Mountain Ash, on June 6, 1897, at the age of fifty-three. He was formerly deputy-manager of the Dowlais Ironworks, and had previously held similar responsible posts at the Blaenavon Ironworks and at the Barrow Hamatite Steelworks. He was elected a member of the Iron and Steel Institute in 1893.

HENRY WATKIN LEWIS, of Abercanaid, Merthyr-Tydvil, died at Harrowgate, on September 10, 1897. He was for many years associated with Mr. Anthony Hill at the Plymouth Works, and with Mr. Crawshaw Bailey at Nantyglo. He was the founder of the Treherbert Engineering Works, now amalgamated with Howell's Dry Dock Company at Cardiff. He was conspicuous for his mechanical and engineering abilities, and on many occasions in colliery accidents risked his life for that of others, notably at Tynewydd, when his services were recognised by the bestowal of the medal bearing that name. He was one of the oldest members of the South Wales Institute of Engineers, a member of the Institution of Mechanical Engineers, and one of the original members of the Iron and Steel Institute.

JOHN EDGAR LOWE died at Blackheath on October 17, 1897, at the age of fifty-eight years. He was a partner in the firm of Bolling &

Lowe of Laurence Pountney Hill, E.C., which he joined on the retirement of the late Mr. James Bird, under whom he had been trained. The firm was well known, and enjoyed a large and important foreign connection. Mr. Lowe possessed an excellent technical knowledge of engineering matters, which was of great value in the management of the firm's extensive operations. He was a member of the Institution of Civil Engineers. He was an original member of the Iron and Steel Institute, and took a keen interest in its meetings, at which he was a constant attendant.

JOHN MALLABAND died at Sheffield on August 24, 1897, at the age of sixty-seven years. He left Coventry about the year 1857 and went to Sheffield, where he started as a moulder. He was appointed manager by the late Mr. Robert Hadfield on the establishment of the works now known as Hadfield's Steel Foundry, and afterwards became a director of Hadfield's Steel Foundry Company, Limited, a position he held at the time of his death. It was largely due to his great practical abilities that the company gained the high standing which they enjoy as manufacturers of steel castings. Mr. Mallaband was elected a member of the Iron and Steel Institute in 1889.

THOMAS REES MORGAN, of the well-known Morgan Engineering Company of Alliance, Ohio, died suddenly on September 6, 1897, at the age of sixty-three. Born in Wales, he left his native country for the United States in 1865, and three years later began business in Pittsburgh as a maker of steam-hammers and other special machinery. In 1871 he went to Alliance, and built the great works that made him famous. He was elected a member of the Iron and Steel Institute in 1882.

ARTHUR GRAEME OGILVIE died at his residence in St. John's Wood, London, on July 29, 1897, at the age of forty-seven. He was educated at Rugby and at Trinity College, Cambridge, graduating in the Natural Science tripos of that University in 1873. He then served a pupillage of three years to Sir George Elliot, Bart., and passed the examination qualifying him for a colliery manager's certificate. From 1878 he practised as a mining engineer in Westminster. He held a leading position in the South Wales district, having been chairman of the Powell-Duffryn Steam Coal Company for several years past, and in 1893 he was chairman of the South Wales and Monmouthshire Coal Owners' Association. He was an Associate Member of the Institution

of Civil Engineers and a Fellow of the Geological Society. He was elected a member of the Iron and Steel Institute in 1883.

✓ CARL OTTO died at Ahrweiler on November 13, 1897. Born in Mexico on March 7, 1838, he was educated at Giessen and graduated at that University as Doctor of Philosophy at the early age of twenty. He completed his education at the School of Mines of Freiberg in Saxony, and worked in the laboratory of various works in the neighbourhood. From 1860 to 1872 he was employed first as chemist and subsequently as technical manager at the firebrick works of H. J. Vygen & Co. at Duisburg. In 1872 he founded the firebrick manufactory of Dr. C. Otto & Co. at Dahlhausen on the Ruhr. Beginning on a small scale, he soon built up a business of great magnitude. Since 1876 the company supplied the various German coalfields with not less than 9922 coke-ovens. By the introduction of the collection of by-products the coke industry became a scientific operation of great complexity. Large capital was required for the plant, and it was problematic whether remunerative prices would be obtained for the products later on. Dr. Otto, however, started the industry by providing complete by-product plant, payment for which was made from sales of the by-products. He was a Member of Council of the Society of German Ironmasters, and a member of the Society of German Engineers. He was elected a member of the Iron and Steel Institute in 1884, and read before the Institute in that year a valuable paper on the most recent results obtained in Germany by utilising the by-products from coke-ovens.

GUSTAV PIEDBOEUF died on November 19, 1897, at his native town of Aix-la-Chapelle, at the age of fifty-four. Member of a Belgian family resident in Germany for three generations, he was the third son of Jean Pascal Piedboeuf, the founder of the various firms bearing that name. After studying for three years in Hanover, he was engaged for a year in England at a bridge-building works. He then joined his father, and since the death of his brother Louis, he assumed, with his brother Eugene, the control of the works, notably the boiler works of Jacques Piedboeuf at Aix-la-Chapelle and Düsseldorf, the sheet-rolling mills at Oberbilk, and the tube works of J. P. Piedboeuf & Co. These four works have independent management. Since 1879 he was also a member of the board of directors of the Oberbilk Steel-works. He was elected a member of the Iron and Steel Institute in 1874.

WILLIAM PUTNAM, of Darlington, died at Bournemouth on May 1, 1897, at the age of sixty-two years. He was for many years the managing Director of the Darlington Forge Company. Up to about the year 1868 he was employed by Messrs Cowans, Sheldon & Co. of Carlisle, and it was in conjunction with that firm that he built the Darlington Forge Works, which are amongst the best known and best equipped in the country. These works he managed with signal success up to the time of his death, and it was largely owing to his great ability in conceiving and adopting new processes and appliances for the manufacture of heavy castings that the Darlington Forge Company held the high reputation which it enjoyed. Mr. Putnam was an original member of the Iron and Steel Institute, and took an active part in organising the meeting of the Institute held at Darlington in 1893.

✓ ALEXANDER THIELEN died at Heidelberg on July 21, 1897. Born on May 3, 1841, at Düsseldorf, he received his technical education at the Clausthal School of Mines and at the Berlin High School. In 1864 he was appointed assistant at the zinc works at Letmathe, and in 1865 entered the service of Sir Hussey Vivian at Swansea. He remained there until March 1870, when he proceeded to South Africa in the interest of the Cape Copper Company. In the spring of 1873 he returned to Germany, and was appointed director of the Phoenix Mining and Metallurgical Company at Laar near Ruhrort. In this responsible position he remained until his fatal illness. In 1880 he founded the Rhenish Westphalian Pig Iron Association, and in 1884 and 1885 he was Vice-President of the International Steel Rail Association. He was a member of the Society of German Ironmasters from its foundation, of which society he acted as president during the International meeting in the United States in 1890. His services on that occasion were recognised by the German Emperor by creating him a Knight of the fourth class of the Order of the Red Eagle, whilst in 1896 the third class of the same distinguished Order was conferred upon him. He was elected a member of the Iron and Steel Institute in 1875, a Member of Council in 1890, and a Vice-President in 1896. He was a regular attendant at the meetings of the Institute, and contributed to its proceedings in 1890 a valuable paper on the Darby process of recarburisation.

ADDITIONS TO THE LIBRARY

DURING THE SECOND HALF OF 1897.

Title.	By whom Presented.
"Sandvik Steel at the Northern Exhibition in Stockholm." 1897. (Pamphlet.)	Messrs. S. A. Edwards & Co.
"Mining Accounts and Cost Sheets." By H. G. Charleton. (Pamphlet.)	The Author.
"List of Mines of the United Kingdom." London. 1897.	Professor C. Le Neve Foster.
"The Smoke Nuisance and its Regulation." Philadelphia. (Pamphlet.)	Mr. F. Lynwood Garrison.
"Trocknen von Thon." By F. Toldt. Leoben. 1897.	The Author.
"Aluminium." Manchester. 1897.	The Aluminium Supply Co., Limited.
"The Wire-Rope and its Application." By W. E. Hipkins. Birmingham. 1896.	Messrs. J. & E. Wright, Limited.
"On the Changes Involved in the Preparation of Basic Steel for Rails." By Professor L. von Tetmayer. Brussels. 1897. (Pamphlet.)	The Author.
"Festigkeits-proben schwedischer Materialien." Stockholm. 1897.	Mr. J. C. Kjellberg.
"Receptacles for Valuable Mineral Deposits." By F. Danvers Power.	The Author.
"Festigkeitskongressen i Zurich." By Prof. H. J. Hannover. Copenhagen. 1895.	The Author.
"Iron and Steel and Allied Industries in all Countries." By J. M. Swank. Washington. 1897.	The Author.
"The Engine, Boiler, and Employers' Liability Co., Limited. Chief Engineer's Report for 1896." (Pamphlet.)	The Company.
"Mineral Statistics of the United Kingdom for the Year 1896." London. 1897.	The Under Secretary of State.

Title.	By whom Presented.
"Prospectus of the Michigan College of Mines," 1897-98. Houghton. 1897.	The Secretary of the College.
"The Simon - Carves Coke - Oven System." Manchester. 1897.	Mr. Henry Simon.
"Gold-Mining Statistics of Western Australia for Half-year ending 30th June 1897."	The Department of Mines, W. A.
"Reports of C. Le Neve Foster, Esq., to the Secretary of State, under the Mines and Quarries Act." London. 1897.	Professor C. Le Neve Foster.
"Programm der Königl. Sächs. Bergakademie zu Freiberg." Freiberg. 1897.	The Director.
"Bulletin of the Department of Labor." Washington. 1897.	Mr. Carroll D. Wright.
"Public Libraries." Vol. ii., No. 8. October. 1897. Chicago. 1897.	The Publishers.
"Kontinuerlig Kolugn." By E. J. Ljungberg. Stockholm. 1897.	The Author.
"Swedish Mineral Statistics for 1896." Stockholm. 1897.	Mr. R. Åkerman.
"Photograph of Exhibit at the Stockholm Exhibition."	Mr. E. J. Ljungberg.
"Catalogue of Mining Machinery." London. 1897.	Messrs. Bowes, Scott & Western, Ltd.
"Labour Problems of To-day." By J. Stephens Jeans. London. 1897.	The Author.
"Transactions of the Australasian Institute of Mining Engineers." Vol. iv. 1897.	The Society.
"List of Quarries in the United Kingdom." London. 1897.	Professor C. Le Neve Foster.
"Chemie des Eisens." By Friedrich Toldt. Leoben. 1898.	The Author.
"Annual Report of the Bureau of Steam Engineering." Washington. 1897.	The Department.
"The Production of Manganese Ores in 1896." By John Birkinbine. Washington. 1897.	The Author.
"The Production of Iron Ores in 1896." By John Birkinbine. Washington. 1897.	The Author.
"Vandergrift Ready." With Plan of Town. (Pamphlet.)	G. G. McMurtry.
"Year-Book of the Royal Society of London." No. 1, 1896-97. London. 1897.	The Society.
"The British Corporation for the Survey and Register of Shipping: Rules and Tables of Scantlings, and Register of Vessels." Glasgow. 1897.	The Corporation.

INSTITUTIONS.

The Publications of the Institute are exchanged for those of the following Institutions :—

LONDON.

Board of Trade.
Chemical Society.
City and Guilds Institute.
Geological Society.
H.M. Patent Office.
Imperial Institute.
Institution of Civil Engineers.
Institution of Electrical Engineers.
Institution of Mechanical Engineers.
Institution of Mining and Metallurgy.
Institution of Naval Architects.
Royal Artillery Institution.
Royal Institute of British Architects.
Royal Institution.
Royal Society.
Royal Statistical Society.
Royal United Service Institution.
Society of Arts.
Society of Chemical Industry.
Society of Engineers.
University College.
West of Scotland Iron and Steel Institute.

PROVINCIAL.

Cleveland Institution of Engineers.
Engineering Society (Leeds).
Hull and District Institution of Engineers.
Institution of Engineers and Shipbuilders in Scotland.
Liverpool Engineering Society.
Liverpool Polytechnic Society.
Manchester Association of Engineers.
Manchester Geological Society.
Mason College (Birmingham).
Merchant Venturer's School (Bristol).
Mining Institute of Scotland.
North-East Coast Institution of Engineers.
North of England Institute of Mining Engineers.
Sheffield Technical School.
South Staffordshire Institute of Iron and Steel Works Managers.
South Staffordshire Ironmasters' Association.
South Wales Institute of Engineers.
University College of South Wales.

COLONIAL AND FOREIGN.**Colonial.**

Canadian Institute.
 Canadian Society of Civil Engineers.
 Department of Mines, Sydney.
 Department of Mines, Melbourne.
 Geological Survey of Canada.
 Geological Survey of India.
 Mining Society of Nova Scotia.
 Royal Society of New South Wales.

United States.

American Association for the Advancement of Science.
 American Institute of Mining Engineers.
 American Iron and Steel Association.
 American Society of Civil Engineers.
 American Society of Mechanical Engineers.
 Bureau of Statistics.
 Engineers' Society of Western Pennsylvania.
 Franklin Institute.
 Ordnance Office, War Department.
 School of Mines, Columbia College, New York.
 Smithsonian Institute.
 United States Geological Survey.

Austria.

K.k. geologisches Reichsanstalt.
 Oesterr. Ingenieur und Architekten-Verein.

Belgium.

Ministère de l'Interieur.

France.

Comité des Forges.
 "Revue Maritime." Ministère de la Marine.
 Société d'Encouragement pour l'Industrie Nationale.
 Société de l'Industrie Minérale.
 Société des Anciens Élèves des Écoles Nationales d'Arts et Métiers.
 Société des Ingénieurs Civils.
 Société Scientifique Industrielle de Marseille.

Denmark.

Tekniske Foreninger.

Germany.

Königliche Bergakademie in Freiberg.
 Königliche Technische Versuchsanstalt.
 Verein Deutscher Eisenhüttenleute. (Journal "Stahl und Eis")
 Verein Deutscher Ingenieure.

Italy.

Reale Accademia dei Lincei.

Japan.

Department of Mines.

Sweden.

Jernkontoret.

JOURNALS.

The following periodicals have been presented by their respective Editors :—

UNITED KINGDOM.

"Bimetallist."
 "British Trade Journal."
 "Coal and Iron."
 "Commerce."
 "Contract Journal."
 "Colliery Guardian."
 "Electrician."
 "Electrical Engineer."
 "Engineer."
 "Engineer and Iron Trades Advertiser."
 "Engineering."
 "Engineers' Gazette."
 "Hardwareman."
 "Hardware Trade Journal."
 "Industries and Iron."
 "Invention."
 "Iron and Steel Trades Journal."
 "Iron and Coal Trades Review."
 "Ironmonger."
 "Ironmongery."
 "Iron Trade Circular."
 "Marine Engineer."
 "Machinery Market."
 "Phillips' Monthly Register."
 "Plumber and Decorator."
 "Practical Engineer."
 "Railway Engineer."
 "Railway World."
 "Shipping World."
 "Statist."
 "Steamship."
 "The London Technical Education Gazette."
 "Tool and Machinery Register."
 "Transport."

COLONIAL AND FOREIGN.**Colonial.**

- "Canadian Mining Review."
- "Indian and Eastern Engineer "
- "Indian Engineering."

United States.

- "Age of Steel."
- "American Journal of Science."
- "American Manufacturer."
- "Bradstreet's."
- "Cassier's Magazine."
- "Digest of Physical Tests."
- "Engineering and Mining Journal."
- "Engineering Magazine."
- "Engineering News."
- "Iron Age."
- "Iron Trade Review."
- "Mines and Minerals."
- "Railroad Gazette."
- "Report of Proceedings of the Master Car Builders' Association."

Austria.

- "Oesterr. Zeitschrift für Berg- und Hüttenwesen."

Belgium.

- "Association des Ingénieurs sortis de l'Ecole des Mines de Liège."
- "Bulletin de l'Union des Charbonnages de Liège."
- "Moniteur des Intérêts Matériels."
- "Revue Universelle des Mines."

France.

- "Annales des Mines."
- "L'Echo des Mines."
- "Le Génie Civil."
- "Portefeuille Économique."

Germany.

- "Annalen für Gewerbe und Bauwesen."
- "Chemiker Zeitung."
- "Glückauf."
- "Verein Deutscher Eisen und Stahl Industrieller."
- "Zeitschrift für das Berg-, Hütten- und Salinenwesen, im preussischen Staate."
- "Zeitschrift für praktische Geologie."
- "Zeitschrift für Werkzeugmaschinen und Werkzeuge."

Italy.

- "L'Industria."
- "Rassegna Mineraria."

Spain.

- "Revista Minera."

Sweden.

- "Teknisk Tidskrift."

SECTION II.

*NOTES ON THE
PROGRESS OF THE HOME AND FOREIGN
IRON AND STEEL INDUSTRIES.*

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IRON ORES.

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I—OCCURRENCE AND COMPOSITION.

Formation of Ore Deposits.—L. de Launay* publishes an important contribution to the study of metalliferous deposits. The memoir extends to a hundred pages, and deals firstly with an attempt to arrive at a theoretical classification of metalliferous deposits, in which the nature and importance of veins of inclusion and of segregation are appreciated; secondly, with the action of surface changes; and lastly, with the application of the views propounded to various metals. The starting-point of every metalliferous deposit should, the author thinks, be sought in an internal metallic bath kept in a molten state by reducing actions in which carbon, hydrogen, and perhaps sulphur, take part. Examples more and more altered, more and more oxidised, are presented; firstly by meteorites, then by peridotites, and lastly by basic rocks. By an examination of such basic magmas, the study of ore deposits ought properly to begin, and it is of special interest to consider from this point of view the new class of deposits that the author proposes to add to the two classic categories of veins and beds. This constitutes a type less altered than the two classes mentioned, and comprises the deposits of inclusion and those of direct segregation, deposits that have remained in absolutely intimate relations with the basic rocks from which all the others are supposed to have been derived. Deep metallic baths of this kind appear to have given, by various methods of derivation, all the rocks forming the earth's crust and all the mineral deposits.

* *Annales des Mines*, vol. xii. pp. 119-228.

A. C. Lane* deals with some of the methods of concentration that have been originated in natural causes and have resulted in deposits of gold, iron, and other ores. Near Samokov, in Bulgaria, streams flowing over plutonic rocks have partially concentrated the magnetite in the river sands, and this is worked up by the peasants. Settlement from molten rock may account for the Nahant gabbro-diorite, which was at one time used in New England as an iron ore. Segregation may sometimes account for nodules of kidney iron ore found in the Michigan Coal Measures. Of the chemical processes, however, precipitation and solution are the most important. Thus the ores of the Mesabi range may be ascribed to the leaching out of the several constituents of the original rock taconite, leaving hematite and limonite. Bog iron ores are quoted as an example of solution and subsequent precipitation. Under different conditions precipitation may result from several causes, such as mixture of solutions, solid precipitants, change of temperature or pressure, escape of carbonic anhydride or evaporation, and possibly electrolytic deposition. Ascending water is most likely to be affected in many of these ways. Ore deposits tend to occur in the line of water currents, in fissures, cavities, porous or soluble rocks, near the contact of chemically dissimilar rocks, where rocks containing the desired elements in small quantities are widespread. The more complicated and eventful the geological history of the region, especially if that history includes faulting, periods of eruptive activity, and subsequent weathering and erosion, the greater is the chance of the concentration of ore bodies.

F. Danvers Power† discusses the nature and origin of receptacles for mineral deposits, a study of which is necessary for enabling them to be worked to the best advantage. Not only open spaces subsequently filled are regarded as receptacles, but also replacement deposits, such as those in which iron oxide has replaced limestone, are included under that term. Receptacles are classified according to their origin into chemical and mechanical, although there is no sharp line of demarcation, and the two causes may operate concurrently. Under the first heading are considered cavities formed by solution and replacement deposits. Mechanically formed receptacles are subdivided into those formed at the surface and those formed underground. The former include fluvial and similar deposits, whilst the latter are those due to bedding, lamina-

* *Engineering and Mining Journal*, vol. lxiii. pp. 542-543.

† *Transactions of the Australasian Institute of Mining Engineers*, vol. iv. A copy of this paper has been presented by the author to the Library of the Iron and Steel Institute.

tion, cleavage, joints produced by contraction, fissures, and faults. Numerous illustrations of these occurrences are given.

Gallium in the Cleveland Iron Ore.—W. N. Hartley and H. Ramage* have found that the element gallium exists in the clay ironstone of the Cleveland district of Yorkshire and in the blast-furnace iron from Middlesbrough. In their second paper on this subject they give in detail the methods used for isolating this metal and determining the amount present. Fractional precipitations are employed throughout, together with spectrographic analysis of the various precipitates and gravimetric determination of the purified gallium sesquioxide. The various operations are described at considerable length, and for these the original paper must be consulted. In part the methods followed are those of Lecocq de Boisbaudran. Experiments on all the raw materials and products show that the gallium exists in the ore, and is concentrated in the metal. It was also found that indium existed in a Spanish manganese ore. Some other British iron ores, including Northampton ore, were found to contain gallium. The gallium in the Cleveland ore was determined after separation by a long series of fractional concentrations and precipitations, and the amount present is given as 0.003 per cent. An attempt, though not so complete, was made to determine the percentage in mixer metal, and the results were closely in accord. In conclusion, the authors state that this metal is the richest source of gallium known. Hitherto it has been obtained from a zinc blende from Bensburg on the Rhine, where it probably is present to the extent of one part in 50,000.

Iron Ore in Cumberland.—Oscar Curtz† gives an account of the occurrence of hæmatite in Cumberland. The ore, he shows, occurs in limestone in beds, in veins, and in masses. As typical illustrations of these three classes he describes:—(1) Parkside Mine; (2) Gillfoot Park, Winder Gill, and Birks Mines; (3) Hodbarrow and Kelton Mines. He deals fully with the methods employed, and gives complete analyses of typical ores, showing in the best grade 59.09 per cent. of iron and 0.0095 per cent. of phosphorus, and in the second grade 43.84 per cent. of iron and 0.0063 per cent. of phosphorus.

Magnetite in Austria.—F. Kretschmer‡ describes an interesting occurrence of magnetite in the Mitteljagd Forest, near Mähr-Altstadt.

* *Proceedings of the Royal Society*, vol. lx. pp. 393–407.

† *Jernkontorets Annaler*, vol. lii. pp. 268–279.

‡ *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlvii. pp. 54–55.

The bed of ore consists of a steel-grey magnetite, usually pure, but occasionally containing garnets, amphibole, chlorite, and muscovite. The proportion of iron varies from 40 to 65 per cent., an average sample yielding the following percentages on analysis:—

Iron.	Manganese.	Silica.	Alumina.	Lime.	Magnesia.	Sulphur.	Phosphorus.
42.18	0.46	29.73	3.24	3.56	0.72	trace	0.83

The deposit courses north and south, and dips at an angle of 40°. It has been opened up by underground working for a length of 200 yards. Its thickness varies from three to four feet.

Iron Ore near Giessen.—At the April meeting of the German Geological Society, F. Beyschlag* read a paper on the iron ore deposits in the vicinity of Giessen. There is a bed of basaltic iron ore, which was worked at the beginning of the century. It consists chiefly of brown iron ore, without phosphorus and manganese. At the foot of this hill there is deposited a flat plateau of alluvial iron ore. A third deposit consists of the manganiferous iron ores, worked on a large scale at three mines near Giessen. The ore is of Middle Devonian age, the thickest bed being 94 feet in thickness. The structure of the iron ore bed shows that it must be regarded as an altered limestone.

The Iron Ores of the Vogelsberg.—According to F. Beyschlag,† iron ore has been mined for many decades at numerous points in the Vogelsberg range. Hitherto it has only been used locally, but is now exported to Siegen and the Lower Rhine districts. The ore is a decomposition product of the basalt and basaltic tuff occurring in this range. It is in consequence of a very impure character, and is found in irregular deposits near the surface, and generally only slightly covered. Only rarely are several deposits of the ore found one above the other, and in such cases they are separated from one another by beds of tuff. Two main types of ore deposits are distinguishable in this district—primary and secondary. In these latter the original deposits of ore have been subjected in the transposition of the ore to a kind of mechanical preparation, in accordance with the varying specific gravities of the substances occurring in the original ore deposit. These latter are rarely more than a few yards in thickness, and are of such a low grade that they are useless as ores of iron until they have been subjected to an enrichment process.

* *Glückauf*, vol. xxxiii. p. 307.

† *Zeitschrift für praktische Geologie*, 1897, pp. 337–338.

The secondary deposits are richer in iron, and contain disseminated true brown hæmatites. The surface of the deposits is often irregular, and they pass, too, irregularly into the underlying basalt. In contradistinction to the primary ore deposits, these secondary deposits scarcely ever outcrop, but are covered by diluvium. The chief points at which this ore is mined are in the neighbourhood of Grünberg. The ore is submitted to mechanical preparation in trommels and on rotating tables, by which it is separated from clay and lumps of basalt and bauxite. In this way a product is obtained which amounts to about 30 per cent. of the total weight of material raised from the mine. It contains about 45 per cent. of iron, 0·2 of phosphorus, and from 0·8 to 1·2 per cent. of manganese. Occasionally, by the aid of other methods of concentration, the percentage of iron is brought up to 50. The ore at present mined is mainly employed in making foundry pig iron at the Buderus Works, near Wetzlar and Giessen, and some is used in the Siegen district. The deposits, though small and low in iron, extend over a very wide area, and are very cheaply mined.

Iron Ore in Corsica.—Nentien * publishes a detailed study of the mineral deposits of Corsica. The memoir covers sixty-five pages, and is accompanied by a map of the island. The deposits described are extremely varied. Anthracite coal is met with at Orsani, and lignite of Eocene age at several places. There is but one iron mine, that of Farinole and Olmeta, which has long lain idle. The ore is magnetite, occurring in lenticular masses in the Pre-Silurian serpentine that forms the two hills north of Farinole. Manganese, though not worked, is met with in amphibolic schists at several places.

Iron Ore in Sardinia.—At a meeting of the Natural History Society of Rhineland and Westphalia, Stockfleth,† read an exhaustive paper on the occurrence of minerals of economic value in the south-western portion of the island of Sardinia. When, some months ago, it was announced that iron ore had been discovered in that district in considerable quantities, little attention was paid to the news. It was, it is true, recognised that argentiferous lead ores had been worked there since ancient times, and that the zinc-mining industry, started thirty years ago, is in a flourishing condition, but no mention had previously been made of the occurrence of abundant and pure iron ores. The

* *Annales des Mines*, vol. xii. pp. 231-296.

† *Stahl und Eisen*, vol. xvii. pp. 534-538.

author has, however, examined the deposits, and reports very favourably upon them.

To the magnetic bed of Leone, near Cagliari, a deposit already worked on a very small scale, four newly-discovered important deposits must be added—namely, the red hæmatite beds of Sissini de Montis, near Nuxis; of Bacchixeddu, near Santadi; and of Chia-Malfatano, near the sea-coast at the Cape Malfatano; and the magnetite bed of Is Crucurris, near Capaterra. The red hæmatites occur in all cases in the form of contact beds between the Silurian schists and limestones and the granite masses. The magnetite is met with in the Silurian schists in the form of a bed as much as 6 yards in thickness. All the iron ores are of extraordinary purity; they average 67 to 69 per cent. of iron. No coal occurs in the island, excepting some seams of brown coal in the small Tertiary basin at Gonnesa, south-west of Iglesias.

Iron Ore in the Southern Ural.—For its rich stores of minerals of economic importance the central portion of the Ural has long been celebrated. Ore deposits are, however, not wanting in the southern portions, and a monograph published by K. Futterer* affords abundant evidence of the importance of the iron ore deposits in the vicinity of Belorezk. At the iron ore mines of Tirlian, limonite has been traced to a depth of 40 feet. At the mines between Belorezk and Kaga argillaceous limonite is met with containing upwards of 53 per cent. of iron and 0.5 per cent. of phosphorus. At the Belski-Rudnik the limonite, containing 50 per cent. of iron, occurs in irregular masses in highly decomposed schists. East of the Ural Tau other important deposits of limonite are met with. The deposits are thought by the author to have been formed by the decomposition and weathering of the schistose rocks and of limestone, the iron contents of which have become concentrated in masses of irregular shape and of varying purity. Owing to these variations, mining is constantly undergoing changes. New points are always being sought, and there is little chance of encountering at any particular locality a supply of ore likely to last for any considerable length of time.

Iron Ore in Spain.—R. W. Barrington† reviews the iron ore industry in Spain during the past year, and considers that the deposits developed recently in Almeria in the south of the country will add

* *Zeitschrift für praktische Geologie*, 1897, pp. 193-200.

† *The Mineral Industry*, vol. v. pp. 371-376.

largely to the shipments in the present year. Until recently ore was only produced in the Bedar district and shipped from Garrucha, but this port will now draw ore from Cañadicas and Serrena, and further to the west from the Sierra la Redonda. Several other districts are mentioned as being opened up along the coast, and many new mines are being developed to supply the new port at Almeria. Chief of these is an enormous deposit of pure ore at Pilatos in the district of Hueneja, fifty miles from the port. Ore outcrops in the district of Fiñana, in the Sierra de Baza, but contains 0.53 per cent. of copper. Better ore in the same district is found in the western extremity of Sierra Nevada. Rich ore is found and worked at Gergal in two ranges about 25 miles from Almeria. Mention is also made of the hard ore from Marbella in the province of Malaga, and of the magnetic iron sand in the same district. In the province of Murcia, immense deposits are found at Cehegin, Calasparra, and they appear to improve on development. In Cartagena no change in the industry is to be noted; no large companies have started, and the means of transport are inefficient. Analyses of many of these ores are given.

Iron Pyrites at Dannemora.—According to A. Larson, in the Dannemora iron mines in Sweden, with the iron ore there occurs iron pyrites which is well suited for the manufacture of sulphuric acid. It contains 41.10 per cent. of sulphur, 48.41 per cent. of iron, 0.16 per cent. of copper, while 1.68 per cent. is insoluble in acid. After roasting at the sulphuric acid works, the mineral contains 6.38 per cent. of sulphur and 57.20 per cent. of iron.

Iron Ore in Newfoundland.—A. E. Outerbridge,* in some notes on the undeveloped mineral wealth of Newfoundland, mentions that iron ores are very plentiful, and that ore has been worked extensively at Bell Isle, Concepcion Bay. The blue billy from Newfoundland pyrites is also used as iron ore.

Iron Ore in India.—R. Bruce Foote † describes fully the geology of the Bellary district, which covers an area of nearly six thousand square miles of the Deccan table-land in the Madras Presidency. Iron ores are specially prominent in this district, although they have as yet been but little used. Magnetic iron ore deposits of gneissic age are unimportant, the

* *Journal of the Franklin Institute*, vol. cxliv. p. 165.

† *Memoirs of the Geological Survey of India*, vol. xxv. (scattered references).

chief beds being those of hæmatite in the Dharwar rocks or lower transition system. In the Kunchar tract, the hills are caused by hæmatite quartzite beds, and in the Raman Drug ridge the Bevihalli bed is of considerable size and persistence. Iron smelting is carried on in three villages, hæmatite being generally used.

Several new discoveries of iron ore have been made during the progress of the geological survey of India, but in view of J. Head's report on the difficulty of locally manufactured charcoal iron competing with the imported product, special investigations of Madras ores would appear to be premature. A hundred tons of the ore from Kanjamalai, near Salem, are to be sent home for an exhaustive trial.*

Iron Ore of Lake Superior.—Some hundred and fifty complete analyses of iron ore from the Vermilion, Mesabi, Marquette, Menominee, and Gogebic ranges have appeared, with details of the ore docks and shipments of ore in the Lake Superior district.†

C. M. Boss ‡ describes some dike features of the Gogebic iron range. The dykes are apparently of dioritic formation, more or less altered, generally ashy-grey in colour, and sometimes dark or almost black, and massive in depth. Practically, all are at right angles to the dip of the formation, and they dip eastward 15° to 18° . Sometimes they are folded into long synclinal basins, but the eastern extremity shows a downward direction. Occasionally they are vertical. At first it was thought that these dikes cut out the ore altogether, but exploration during recent years has shown that this is not so. At the Norrie mine a borehole passed through several dikes and ore bodies, of which the upper ones have been proved by mining operations. The author then gives a description of the numerous dikes that have been found in the district.

Iron Ore in New Jersey.—The annual report of the State Geologist of New Jersey contains, besides the general statement of progress during the year 1896, eight special reports. In one of these G. E. Jenkins gives many particulars regarding the iron mines. Some of the New Jersey mines have been of great importance in their time, but during the last five years only the old and larger mines have been

* *Records of the Geological Survey of India*, vol. xxx. p. 3.

† *Transactions of the American Institute of Mining Engineers*, Lake Superior Meeting, July 1897 (advance proof).

‡ *Ibid.*

worked, and no new ones have been opened. While the number of mines has decreased, the output of those worked has increased.

Limonite in North Carolina.—H. B. C. Nitze* describes the iron ores in Cherokee county, which is the most south-westerly county in North Carolina. The ores are mostly limonite, and occur in the south-east and north-east of the district, and were worked as early as 1840 in Catalan forges. This industry ceased in 1888, and no other mining operations have been undertaken. The ores occur in beds of good body and extent, in calc schists, which have been allotted to both Carboniferous and Cambrian formations. The most important deposits are the Valley River and the Noatla River ore belts, and the various occurrences of ore are described in some detail by the author, who gives numerous analyses. These indicate that ore in large quantities could be obtained with silica between 5 and 15 per cent., and iron from 43 to 57 per cent. Sulphur is low as a rule, but phosphorus is variable, and always above the Bessemer limit, ranging from 0.10 to nearly 1.00 per cent. Manganese is usually present in quantities less than 2 per cent., and it is mentioned that these ores are very often auriferous. Limestone low in silica may be obtained in large quantities, and timber for charcoal is abundant.

The Iron Ores of the Southern United States.—C. Haller† discusses the iron industry of the United States in reference to its commercial competition with other countries. Dealing first with the Southern States, he discusses the subject largely as the result of a personal investigation made by himself. Some of the ore seams mined reach 12 to 22 feet in thickness, whilst in Alabama 50 feet is met with. In many places the seams crop out. Near Birmingham, Alabama, this occurs, and in addition the ore seams are overlain by a valuable coal deposit. As many as twenty-five seams are met with in the coalfield, of which this forms a part, in which a bituminous caking coal, varying from 3 to 14 feet in thickness, is mined. Within a radius of five miles from Birmingham red hæmatite, coking coal, and flux are found.

The chief iron ores in the Southern States may be divided into two divisions—(1) Pockets and irregular deposits of brown hæmatite, with about 50 per cent. of iron and from 0.1 to 0.4 of phosphorus. These ores are found in clay and are raised by steam-shovels, then washed

* *Engineering and Mining Journal*, vol. lxiii. pp. 330-331.

† *Stahl und Eisen*, vol. xvii. pp. 439-444.

free from the clay, and either smelted direct or after calcination. This brown iron ore forms at present about 25 per cent. of the total quantity of the ore mined. (2) Red hæmatite, occurring in regular seams. The ores are richest in the upper portions of the deposits, containing about 40 per cent. of iron. Here, too, they are richest in lime and lowest in silica—up to 20 per cent. of the former, and down to 10 per cent. of the latter. The more closely the bottom of the seam is approached, the lower does the ore get in iron. The percentage of lime, too, diminishes, whilst that of the silica increases. As a rule, the upper ten feet of ore is used as mined, and without any subsequent preparation. This contains from 37 to 40 per cent. of iron, 12 to 20 per cent. of lime, and about 0·3 to 0·4 per cent. of phosphorus. In places the more siliceous deeper lying ore is also mined, and is then concentrated. Where the ore outcrops it has undergone change. Lime has been washed out and the iron contents increased by some 10 per cent. As a rule, this alteration is shown along the whole outcropping edge of the deposit, and for a depth of 300 feet within it. This leads to a further classification in the Southern United States of the ore into (a) hard hæmatite and (b) soft hæmatite, both kinds passing the one into the other. The hard ores are richer and easier to smelt; and the soft ores, which include the brown hæmatites, are cheaper to mine. Occasionally in smelting these latter, instead of adding lime or dolomite as flux, hard hæmatite, containing an excess of lime, is used instead.

Besides the ores above mentioned, blackband ores and magnetites are also found. The wet "soft hæmatite" contains 7 per cent. of water, whilst the wet "brown hæmatite" contains 7 per cent. of hygroscopic water and 6 per cent. of combined water. The calcined brown iron ore contains up to 56 per cent. of iron. The following are average analyses of the ore :—

Description.	Soft Hæmatite.		Hard Hæmatite.		Brown Hæmatite.	
	Wet.	Dried.	As Mined.	Calcined.	Wet.	Calcined.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Iron	47·24	50·80	37·00	42·15	48·54	51·00
Silica	17·20	18·50	13·44	15·31	11·22	9·00
Alumina . . .	3·35	3·60	3·18	3·62	3·61	3·75
Lime	1·12	1·20	16·20	18·46	0·84	0·75
Carbon dioxide .	...	...	12·24	...	...	...
Phosphorus . .	0·4	not det.	0·37	not det.	0·38	0·4
Sulphur . . .	0·1	not det.	0·07	not det.	0·09	0·1

With regard to the metallurgical preparation of the poorer ores, to which reference has already been made, in addition to the ordinary washing process, calcination is also occasionally employed. This is effected in gas-heated shaft-furnaces, which yield daily about 120 tons of calcined ore from 140 tons of raw material. Producer gas is employed, about 60 lbs. of coal being required for every ton of calcined ore produced. Coke-oven or other waste gases are also employed. The selling price of the ore is referred to, and it is pointed out that the ore is frequently broken down before charging to pieces of from 0·5 to 1 inch in size, this being stated to cause a considerable saving in the coke required in the blast-furnace. The cost of mining is referred to, and in the case of the upper ten feet in soft hæmatite this is stated to amount to 40 or 50 cents a ton.

The limestone used in the blast-furnace contains usually 4 per cent. of silica, 1 per cent. of iron oxide and alumina, and 94·6 per cent. of calcium carbonate. Of late, dolomite has been frequently used instead of lime. It is stated to prove beneficial in the removal of sulphur. As a rule, it contains 1 to 1·5 per cent. of silica, 1 per cent. of iron oxide and alumina, 54 per cent. of calcium carbonate, and 43 per cent. of magnesium carbonate.

An illustrated description has been published * of the occurrence of iron ores in the Southern United States.

The *Age of Steel* † publishes a series of photographs of typical iron ore deposits and limestone quarries in the famous Coosa Valley region of Alabama. They afford a remarkable illustration of the great natural advantages enjoyed by the iron-making interests of Alabama.

W. M. Brewer ‡ gives a brief account of the mining industry in the Cartersville district of Georgia, which is adjacent to Cherokee county. Iron ore was at one time worked and smelted on the Etowah river, and near by ochre is still worked from a deposit covering about five acres and of considerable thickness. Manganese ore to the extent of a thousand tons annually is produced in this district.

Magnetic Properties of Iron Ore.—Specular iron ore is peculiarly interesting from the facility with which it lends itself to the study of a variety of physical properties depending upon crystalline structure. Some time ago, Bäckström studied the phenomena of thermal expansion,

* *Iron and Coal Trades Review*, vol. lv. p. 343.

† Vol. lxxii. No. 10, p. 22.

‡ *Engineering and Mining Journal*, vol. lxiii. p. 575.

thermal and electrical conductivity, and thermo-electric force in their relation to the axis of symmetry. This was done by cutting rods of the substance in various directions. These studies have now been extended to the magnetic properties by J. Westmann.* He found that slabs of the ore immersed in a strong magnetic field were magnetised, but that the magnetic axis often made a small angle with the direction of the original field. The magnetic permeability was 0·2 per cent. of that of wrought iron, and the ore showed high coercive force. It was paramagnetic in every direction.

A large number of iron ores, mostly oxides and sulphides, collected from the mines of Transylvania, have been examined by A. Abt † as regards electric conductivity. Prisms of magnetite, pyrrhotite, copper pyrites and hæmatite were pressed between lead plates to obtain a good contact. The values obtained were fairly consistent. On repeating the measurements twenty times, the resistances of copper pyrites were found to diverge about 0·9 per cent. throughout the series, while those of magnetite diverged about 2 per cent. But while consistent in themselves, it was found impossible to attribute a certain definite conductivity to each mineral.

Native Iron.—E. T. Allen ‡ gives the following three analyses of native iron found when drilling wells at Cameron, Weaubleau, and Holden, in Missouri.

Sample.	Fe.	SiO ₂ .	C.	P.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
I. . . .	99·16	0·37	0·065	0·207
II. . . .	99·39	0·31	...	0·130
III. . . .	97·10	1·65	...	0·176

The first of these was found in sandstone, and had a lamellar structure, and the others in clay. All were found at such a depth from the surface, and under such conditions, that there can be no doubt of their terrestrial origin, and they could not be portions of the drill. They were all found in the Coal Measures. Nickel is entirely absent, so that they are not likely to be of meteoric origin.

* *Beiblätter*, 1897, No. 9; *Electrician*, vol. xl. p. 36.

† *Ibid.*, 1897, p. 744; *Ibid.*, vol. xl. p. 36.

‡ *American Journal of Science*, vol. iv. pp. 99-104.

Recent Researches on Meteorites.—According to S. B. Mirat,* the analysis of a meteoric stone which fell at Madrid on February 10, 1896, gave the following results:—

SiO ₂	MgO.	Fe.	FeS.	Fe ₂ O ₃	Al ₂ O ₃	Ni.	CaO.	MnO ₂
58·86	15·95	7·75	7·23	5·11	2·36	1·30	0·51	0·08

Phosphorus, chromium, copper, sodium, potassium, lithium, and nitrogenous compounds, which amounted in all to 0·85 per cent., bring the total to 100. The specific gravity is 3·6189 at 15° C., and the hygroscopic moisture amounted to 0·2841 per cent.

H. Laspeyres† describes a new meteoric mineral which he names Kosmochlor, and also some stony enclosures of the Toluca meteorite, Mexico. On treatment of the oxidised surface of the Toluca meteorite with acid, an insoluble residue was obtained having a composition which, by calculation, shows the insoluble residue to have consisted of 2·45 per cent. of orthoclase, 25·26 per cent. of plagioclase, 37·40 per cent. of augite, and 34·89 per cent. of quartz. The plagioclase consists of a mixture of 3 molecules of anorthite with 4 of albite, and is therefore similar to that found by Tschermak in the Gopalpur meteorite. In the solution was found some tin, no phosphoric acid, iron, aluminium, calcium, potassium, sodium, traces of nickel, and no traces even of chromium or zirconium.

Kosmochlor the author names a mineral which was also present in this meteorite, and insoluble in all acids. On fusion with nitre it passes into solution, and can afterwards be dissolved in water, yielding a colourless solution. Analysis showed it to have the following percentage composition:—

SiO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	CaO.	MgO.
32	9	39	9	6	5

The insoluble residue, consisting mainly of this mineral, had the specific gravity 3·158. The hardness is 5–6, and it is infusible. The author describes the mineralogical properties of this mineral in detail.

According to E. W. Cohen,‡ the meteoric iron from Locust Grove, North Carolina, weighing 23 lbs., was found July 29, 1857, and was kept at a house in Georgia until 1895. A bright meteor was seen in the locality on July 26, 1857, but the very thin coating of rust on the surface of the iron is probably more than would have been formed in three days. The structure is granular, with an absence of octahedral and twin

* *Bulletin de la Société Chimique*, vol. xv. p. 1070.

† *Zeitschrift für Krystallographie und Mineralogie*, vol. xvii. p. 586.

‡ *Sitzungsberichte der Berliner Akademie*, 1897, pp. 76–81.

lamellæ; the etched surfaces of the grains show numerous minute rounded elevations. In the outer portion of the meteorite nodules of graphite and troilite, and a platy phosphide of iron and nickel are present, whilst in the central portion there is rhabdite. Analysis by O. Sjöström gave—

Fe.	Ni.	Co.	Cu.	C.	S.	P.	Cl.	Total.	Sp. Gr.
94.30	5.57	0.64	trace	0.02	0.05	0.18	0.01	100.77	7.7083

This corresponds with the following mineralogical composition:—

Kamacite.	Fe ₂ NiP.	Troilite.	Lawrencite.
98.70	1.16	0.12	0.02

E. W. Cohen * describes a meteorite found in Forsyth county, Georgia. A series of analyses are shown, of which the following are two of material taken from widely separated portions of the mass:—

					Granular Variety.	Dense Variety.
					Per Cent.	Per Cent.
Iron .	.	.	.	.	94.18	94.03
Nickel .	.	.	.	.	5.56	5.55
Cobalt .	.	.	.	.	0.60	0.53
Copper .	.	.	.	.	0.02	0.02
Carbon .	.	.	.	.	0.04	0.02
Sulphur .	.	.	.	.	0.05	0.03
Phosphorus .	.	.	.	.	0.19	0.23
Chlorine .	.	.	.	.	0.17	...

The dense variety forms six-sevenths of the whole mass, the granular portion representing the remaining seventh. Troilite and graphite are present in relatively considerable quantities, and rhabdite and schreibersite in smaller proportions. The specific gravity of the granular portion was 7.3357, and of the dense part 7.4954.

According to O. A. Derby,† the Bendego meteorite found in 1784 weighs 11,800 lbs. It is now in the Rio de Janeiro Museum. Detailed accounts are given of its history and external form. Some planes of easy fracture, which mark the junctions of different crystalline individuals of the iron, are called "Wollaston planes." With the exception of troilite nodules and patches of cohenite, the iron consists essentially of kamacite, there being very little tænite (about 0.1 per cent.), and probably no plessite, so that the Widmanstätten figures do not stand out in relief on

* *Sitzungsberichte der Berliner Akademie*, 1897, pp. 386-396.

† *Archivos Museo Nacional, Rio de Janeiro*, vol. ix. pp. 87-184; *Journal of the Chemical Society*, vol. lxxii. p. 416.

the etched surface, but are visible as an oriented sheen. On the etched surfaces of the kamacite individuals are the so-called file markings, together with systems of fine raised lines, called "Bendego lines," which are apparently due to lamellar twinning (parallel to the faces of the hexakisoctahedron [421]), as are the Neumann lines of hexahedral iron. Analysis of the bulk of the iron, which represents almost pure kamacite, gave I. (by Dafert), and a partial analysis by G. Florence is given under II. This agrees with the formula, Fe_{14}Ni , for kamacite. The troilite gave the results under III. (also a trace of silica). The residue probably consists of daubréelite and schreibersite. Cohenite is abundant, and is seen on the cut surface as embroidery-like patches. Measurements given by E. Hussak of the imperfect crystals show them to be isometric: specific gravity, 6.1805; analysis IV., by Dafert, after deducting 5.72 per cent. of schreibersite. The schreibersite and rhabdite gave analysis V. (also a trace of tin); measurements are given of the tetragonal rhabdite needles. Analyses were made of another phosphide of iron and nickel of uncertain nature, which remains as a black powder when the iron is dissolved in dilute acid. Some chromite, rich in crystal faces, hypersthene, and "magnetic globules" are also present. Carbon was shown to be absent in the gas evolved when the iron is dissolved in dilute acid.

	Fe.	Ni.	Co.	Cu.	P.	C.	S.	Insol.	Total.
I.	93.06	6.83		...	trace	...	...	0.38	100.22
II.	...	6.36	0.79	0.0045	...	...	...	...	...
III.	62.51	trace trace		...	...	...	33.24	5.26	101.01
IV.	90.16	3.62		...	trace	6.39	...	...	100.17
V.	52.42	33.51		0.25	15.09	...	...	...	101.27

R. C. Hills* describes the meteorite recently found in the foothills of the Oscura mountains in Socorro county, New Mexico. Three irregular specimens, weighing $1\frac{1}{4}$, $3\frac{1}{4}$, and $3\frac{1}{2}$ lbs. were found. Analysis showed:—

Fe.	Ni.	Co.	P.	C.	Total.
90.79	7.66	0.57	0.27	0.07	99.36

Lieutenant Peary† has brought back the Cape York meteorite from the Arctic regions. It is variously said to weigh from 70 to 100 tons.

* Paper read before the Colorado Scientific Society, April 1897, through the *Engineering and Mining Journal*, vol. lxiii. p. 382.

† *Daily Graphic*, October 16, 1897; *Industries and Iron*, vol. xxiii. p. 337.

Illustrations have appeared of the operations of removing it from the vessel. It is to be placed in the Museum of Natural History at New York. It was reported in 1818 by Sir John Ross, but as it lay in 20 feet of water it was difficult to raise. The Eskimo have been in the habit of chipping off pieces to make spear-heads and knives.

Manganese Ore in Greece.—According to Cottrell,* an impetus has been given to the manganese mining industry of the island of Milo by the recent increased demand for the ore. Beds of manganese of 2 to 6 feet in thickness occur deposited on trachyte, and overlain by Tertiary strata. The ore is mixed with various kinds of clay, which, however, may easily be removed. This is done by screening after the ore has been stamped, but it is intended to introduce improved methods, and to replace manual labour by machinery.

Manganese Ore in Huelva.—At a meeting of the German Geological Society, Professor Klockmann† described a deposit of manganese ore recently opened up in the Spanish province of Huelva. Manganese ores have long been worked on a large scale in the province, but until recently workings were confined to the pyrolusite at the outcrop. Recent explorations have shown that the ore at greater depths consists of a mixture of manganese carbonate and silicate of great and uniform thickness. The deposits are stratified conformably with the enclosing strata, and are similar in character to the deposits of pyrites occurring in the vicinity.

R. W. Barrington‡ states that there has been renewed activity in manganese ore mining in Huelva, Spain, where the mines in depth have shown considerable quantities of carbonate of manganese. Rich deposits have also been found in Oviedo, Asturias, and Teruel.

Manganese Ore in the Bellary District, India.—R. B. Foote§ states that manganese ore is met with in four localities in the Bellary district in the centre of the Deccan table-land, and sufficient quantities are found to be worth working. One analysis is as follows:—

Insoluble.	$\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$.	MnO_2 .	CaO .	H_2O .
38.96	12.82	42.90	0.78	3.83

* *Foreign Office Report.*

† *Glückauf*, vol. xxxiii. p. 433.

‡ *The Mineral Industry*, vol. v. p. 420.

§ *Memoirs of the Geological Survey of India*, vol. xxv. pp. 194–196.

It appears to be braunite or hausmannite. The ore occurs in nodules, in schist and argillite, and could easily be quarried.

Manganese Ore in Java.—Pyrolusite is found at two places in the Joguia province, near Wada, and in the Keliripan mountains. Here a bed of the ore is mined varying from 0·5 to 1 yard in thickness. The ore is met with at various other places.*

Manganese Ore in the United States.—In Colorado, Michigan, and Wisconsin, manganiferous iron ore is produced, that of the latter two States assaying 4 to 10 per cent. of manganese, whilst the Colorado ore contains 25 to 30 per cent. In New Jersey the product is chiefly franklinite residuum from the zinc furnaces. This material is smelted to spiegeleisen at three works which produced 12,403 tons in 1896. Other States produce chiefly pyrolusite. The Colombian, Russian, and other deposits are also shortly described.†

Manganese ore mining, according to W. M. Brewer,‡ has been carried on in Georgia for nearly fifty years, and up to 1896, 66,318 tons have been produced. The principal deposits worked are in Bartow and Floyd counties, at the Cartersville and Cave Spring districts, but ore is also found in Cartoosa county. Ore is usually prepared for market by screening instead of washing. Workings are usually open cuts, and are not on a large scale. The ore is found in pockets, and contains 44 per cent. of manganese on an average.

C. Catlett§ describes the manganese ore deposits which attain their greatest development along the western base of the Blue Ridge in Virginia, in a well-defined belt, a short distance above the Potsdam Sandstone. The manganese ores often pass into iron ores, and are persistent over 150 miles. The ore is mostly psilomelane in small nodular forms, or concretionary layers, and it occurs in beds of clay, which average four feet in thickness at Elkton. Analyses show:—

Silica	.	.	.	15·00	10·60	12·30	5·25	3·25
Iron	.	.	.	2·80	1·45	1·45	11·30	0·97
Phosphorus	.	.	.	0·114	0·116	0·125	0·196	0·10
Manganese	.	.	.	42·61	47·06	46·59	44·56	47·37

Two forms of secondary deposits are also found, one caused by washing down, and the other by solution and redeposition.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 418.

† *The Mineral Industry*, vol. v. pp. 415–419.

‡ Paper read before the Alabama Industrial and Scientific Society, through the *American Manufacturer*, vol. lx. p. 440.

§ *Engineering and Mining Journal*, vol. lxiv. pp. 156–157.

Manganese Ore in Brazil.—Extensive deposits of manganese have been discovered in the province of Minas, Brazil. Two cargoes of the ore have been sold in England. It contains 50 per cent. of manganese, 0.04 per cent. of phosphorus, and 0.92 to 1.70 per cent. of silica.

Nickel Ore in Norway.—J. H. L. Vogt* endeavours to prove that the best Norwegian nickel deposits (in Evje and at Ringerike) might very well compete with the Canadian and New Caledonian ores if they were smelted in a scientific manner (direct concentration of the calcined ore for the Bessemer process, and refining of the Bessemer regulus by the Mond process). He calculates that from the Norwegian ores, containing from 1.7 to 2.25 per cent. of nickel, a calcined product might be obtained with 10 to 16 per cent. of nickel, and that metallic nickel could be made at about 10d. per lb., whilst Canadian or New Caledonian nickel costs half as much again. The advantage of the higher percentage of metal in the Canadian ores (somewhat less than 3 per cent.), compared with the Norwegian, is counterbalanced by the higher cost of wages and of coal.

II.—IRON ORE MINING.

Iron Ore Mining in the Lake Superior Region.—Professor F. W. Denton† describes the methods of iron ore mining in the Vermilion and Mesabi ranges in Northern Minnesota. A sketch map of the country is given to show the ranges and railways, and numerous plans, sections, and photographic illustrations of the mines are given. In the Vermilion range the Minnesota and Chandler mines are described, with special attention to the pumps and crushers. At the latter mine a caving system is in use, and has interfered greatly with the shafts owing to the caving extending farther than was expected. Most of the ore is obtained below the sixth level. Above the eighth level main levels are driven seventy-five feet apart, and raises put up every fifty feet, from which four series of sub-drifts are run, leaving a mass of ore honey-combed with drifts, with about eight feet of ore between them as pillars. These are sliced out, and the top caved from above downwards. Below

* *Norsk Teknisk Tidsskrift*, 1897; *Zeitschrift für praktische Geologie*, 1897, p. 335.

† *Transactions of the American Institute of Mining Engineers*, Chicago Meeting, February 1897 (advance proof).

the eighth level intermediate levels are driven to leave ore blocks twenty feet thick, and the raises are omitted.

On the Mesabi Range the deposits are beds of great area and relatively small depth, dipping to the south at low angles, and covered with glacial drift, varying in thickness, in the developed mines, from 2 or 3 to 100 feet. Although generally considered to be a district of open-pit mining, the Mesabi has really only five deposits which are worked strictly by open pits. There are about twelve purely underground mines, and three or four that use a combination of underground and open-pit methods. The output for the past year, however, gives the lead to the open-pit mines, which have furnished about one and a half million tons, while the product of the underground mines was about one million, and that of the others about half a million tons.

The Mountain Iron Mine is especially adapted to mining with steam-shovels. Two locomotives are used for each shovel, one to handle the empty and the other the loaded trucks, and the largest shovel is said to have produced a daily average of 3458 tons in ten hours during one month. The ore is just loosened by blasting, and eight men work with each shovel. The ore is sampled 20 to 50 feet ahead in order to guide the loaders. The Oliver Mine is also worked open-cast, one shovel weighing 80 tons. The ore lies in a gently sloping side hill; and after the stripping had been done, a cut was carried into the ore, starting at the foot of the hill. This cut was then widened by alternate stripping and slicing by the steam-shovel. The gradient is now against the loaded trucks. To drain the ore a shaft has been sunk.

The Auburn Mine is selected as an example of the mines employing underground mining combined with stripping. This method of extraction is locally termed the "milling" system. Two levels have been opened out, the first level having about 65 feet of ore over it, and the second about 60 feet, and timbered, and from this the branch drifts were opened at 45°, or at right angles. From all the drifts raises were carried up to the top of the ore, which had been previously uncovered. The ore is "milled" down through them from the surface, trammed to the shaft and hoisted. The first raises are placed 40 feet apart, and when these are mined out, a second series of raises is put up half-way between the first, to tap the pyramid of ore left between the first. The raises occasionally become clogged, but no serious difficulty is experienced. Holes are drilled around the sides of the craters by driving down, with sledges, pointed 1½ inch steel rods 5 to 18 feet long, this operation taking ten minutes to an hour with two to four strikers. To

draw these rods—which often stick very tight—clamps are fastened to the tops and railroad jacks are placed under the projecting arms of the clamp. The holes are first “chambered” with three or four sticks of 50 per cent. dynamite, and then charged with three to ten 25-lb. kegs of black powder. By constantly sampling the ore, it is graded into two classes, carrying respectively 64.95 per cent. of iron and 0.049 per cent. of phosphorus, and 62.5 per cent. of iron and 0.065 per cent. of phosphorus.

The Fayal Mine is the most extensively developed of the purely underground mines. All the ore is made into one grade, containing 62.5 per cent. of iron and 0.038 per cent. of phosphorus. There is from 65 to 90 feet of surface over the ore. The top of the ore slopes south, as shown by a map given. The method of mining has been by rooms, and by top-drifting and caving. The rooms are made about 24 feet wide, with pillars between of about the same width or a little less. The rooms are carried up to the overlying sand, which may make them as high as 65 feet; the length may reach 300 feet. All the rooms are filled, after they are completed, by running in the glacial drift that forms the roof, from the top of a raise put through to the surface for the purpose. When rooming is not employed, raises are put up to the sand, and from the tops of these raises, what are called “sub-drifts” are put through the ore, dividing it up into a series of blocks or pillars, one drift-set high. These “subs” are timbered with drift-sets. One series of subs is not extended under the one above, as a rule, until the upper one has been worked out; and, when necessary, in order to reach timber or ore chutes, the drifts are staggered so that the roof of the lower drift does not come entirely under the floor of the upper drift. After blocking out the ore by these drifts, the pillars or blocks are mined by slicing and caving—i.e., a drift will be run along the farther side of a pillar; then this drift will be caved, and a second slice taken off alongside the first; and the operation will be repeated until the block has been mined. Each slicing-drift is not run entirely across the block; but two drifts are started, one from each side, to meet half-way down the side of the block. Before caving these slicing-drifts, 1-inch boards of the cheapest grade obtainable are placed over the bottom of the drift, to keep the sand from mixing with the ore mined from the next lower series of drifts. The raises used for ore-chutes are placed about 100 feet apart; and, thus far, regular mine cars, running on tracks, have been used in the sub-drifts. Recently the experiment has been tried of putting in what are termed at the mine “stull-rooms.” The top of the room is

first cut out by driving a wide drift just under the sand, and supporting this drift by saddle-back timbering, which becomes the roof of the room. This roof timber is put in by driving from sub-drifts on the same level, thereby avoiding the hoisting of timbers. The rooms could be started from the tops of raises, if necessary. After the roof is thus securely supported, the ore is stoped underhand, through the raises, to the drift in the centre of the bottom of the room, where it is run into the cars and trammed to the shaft. The sides of the room are left unsupported; and the doubtful part of the experiment was whether these sides would stand. A number of rooms have already been mined in this way, without any trouble whatever; and, at least for the Fayal deposit, the experiment seems to be successful. The shaft is sunk in ore as close to the rock as possible, at an angle of 66° with the horizontal. Underground ore pockets are being generally adopted, and make tramming and hoisting independent of each other for a short time. The tramming is done by hand in the sub-drifts, but for long tramming on the main level mules are used, and have been found to reduce the cost materially. A special feature of the Fayal Mine is the use of "timber slides" for getting timber into the mine. These slides are made by putting up raises to the surface, 5 feet by 5 feet in section, and equipping them with skidways, down which the timber is allowed to slide. The skidways are curved at the bottom, to diminish the velocity of the timber. The angle of the first slide was 45° ; but the later ones were put at 38° , which is considered to be about the best angle. The men are made to travel in and out of the mine through inclined raises specially prepared for them, so as to lessen the chances of fire in the main shaft.

The Genoa Mine, which is just being developed, is also described briefly, and also the group of mines at Hibbing. The author then discusses the relative values of underground roads laid out on the diagonal and rectangular plans. The former is better for tramming, and the latter for support. Possibly a combination would be preferable, although it has not been tried. Another difference is the method of handling square-set rooms after they are completed. In one system, the rooms are caved by blasting in the roof and timbering, whilst in the other they are filled from the surface through raises. The former causes loss of pillars, and although rooming is economical in first cost, the remaining ore is not readily extracted. Other points of difference are also discussed. Mining on the Vermilion range has reached a fixed system, but no company appears to be satisfied with the methods on the Mesabi range.

H. V. Winchell* gives a general account of the mines of the Minnesota Iron Company, together with photographic illustrations of the Minnesota, Chandler, Auburn, and Fayal mines, to show the surface and underground workings, shafts, and also the shipping arrangements.

D. H. Bacon† traces the development of the Lake Superior iron ores, briefly describing the increase of facilities for transport, the decrease in the price of mining and carriage, and referring to the various systems of working the ore by mining, milling, caving, steam-shovels, the use of rock-drills and explosives. The future of the district is also shortly discussed.

H. J. Stevens‡ gives some particulars of the conditions of the mining industry in the Lake Superior district at the end of August.

The schedule governing the prices of Bessemer ores from the various Lake Superior ranges has appeared.§ Allowance is made for the percentage of iron and moisture present, and a table is given to show the allowance for each 0.001 or less per cent. of phosphorus between 0.0275 and 0.070 per cent.

The Fauck System of Drilling.—In a paper read before the Austrian Society of Engineers and Architects, A. Fauck|| described his system of drilling. The author first dealt with other systems in general use, and then by the aid of a model explained the modifications he had introduced.

Preliminary Hoisting Plant for Mines.—R. Peele¶ describes some of the hoisting appliances appropriate for temporary work or preliminary work in mines. The hand-windlass and various forms of horse-whims are dealt with, illustrations and dimensions being given. With a hand-windlass and single unbalanced bucket two men cannot raise more than 6 tons from a depth of 100 feet in eight hours, and a duty of not more than 4 or 5 tons should be expected. With balanced buckets and four men a maximum duty of 18.85 tons may be expected. With a one-horse whim and unbalanced bucket 15 tons may be raised 250 feet in ten hours. With two horses a gross load of 800 lbs. can be

* *Engineering Magazine*, vol. xiii. pp. 872-895.

† *Transactions of the American Institute of Mining Engineers*, Lake Superior Meeting (advance proof).

‡ *American Manufacturer*, vol. lxi. pp. 299-300.

§ *Engineering and Mining Journal*, vol. lxiii. p. 402.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. Beilage, pp. 54-56; one illustration.

¶ *School of Mines Quarterly*, vol. xviii. pp. 85-93.

raised 50 feet per minute in regular work. It is generally better to increase the speed than the load, as small buckets can be handled more easily. Light steel buckets weigh 200 to 300 lbs., and steel rope, $\frac{1}{2}$ to $\frac{5}{8}$ inch diameter, weighing 0.35 to 0.60 lbs. per foot, is used. In Mexico "malacates" or mule-whims, with overhead drums of considerable size, are employed, being built for use with eight to twelve mules.

Mine Shafts.—At the Engineering Congress of the Institution of Civil Engineers, Bennett H. Brough * discussed the future development of deep-level mining in the United Kingdom. In his paper he advocated the use of shafts of circular section lined with iron in metalliferous mines. W. Thomas also dealt with the prospects of deep mining in Cornwall.

Underground Temperature.—W. Hallock † gives the particulars of underground temperature determinations at Wheeling, Western Virginia, and at Pittsburgh, Pennsylvania. The well at Wheeling is 4500 feet deep, $4\frac{7}{8}$ inches in diameter, and dry. The strata dip only 50 feet per mile, and are mostly of shale. The temperature near the bottom is 110.15° F., and the rise is 1° F. for 80 to 90 feet in the upper part and 1° F. for 60 feet nearer the bottom. When plotted, it is seen that the rise shows a nearly uniform curve. Two years later the hole had filled with water, and observations to a depth of 3200 feet showed that the temperatures were practically unaltered. There did not appear to be any water or air circulation in the boring. At Pittsburgh, in February 1897, a well had been sunk to a depth of 5386 feet, with a diameter of $6\frac{1}{8}$ inches. The temperature at the bottom was 127° F., giving almost identical results with the Wheeling well. Temperature readings made at 2250 and 2350 feet above and below a feeder of gas showed a cooling due to gas expansion of 14° F.

According to Libert, ‡ experiments made at the Sainte-Henriette shaft show that there is no regular increase of temperature with increasing depth, but that at first it increases slowly and subsequently with greater rapidity. The shaft is 3773 feet deep. For the first 650 yards the temperature increases 1° C. for every 98 to 115 feet, and from 650 yards downwards 1° C. for every 76 to 79 feet. These results are not identical with those observed at the deep bore-hole at Paruschowitz.

* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxx. p. 201.

† *School of Mines Quarterly*, vol. xviii. pp. 148-153.

‡ *Annales des Mines de Belgique*, vol. ii. Part I.

Rock-Drills.—According to N. Hedberg,* rock-drills have been in use in the Dannemora district since 1891 with complete success. The compressor used can yield a pressure of 96 lbs., but as only four drills are at work, it is only run at half speed, and yields about 40 lbs. The air is brought up to about four atmospheres excess pressure, and collected in a cylinder having a cubic capacity of 459 cubic feet. Thence it passes to a pipe line 5.9 inches in diameter, and down 706 feet to the chief working place in the mine. Here the pipe first diminishes in section to 2.95 inches and then to 1.97 inch. Subsequently the pipe branches, and india-rubber tubes lead the air up to the working spaces. Here it reaches a "separator" which can feed three drills through pipes 0.98 to 1.38 inch in diameter. Before, however, the air actually reaches the drills it is passed through a spirally wound pipe in a chimney heated by a charcoal fire. This increases its effect, and prevents too great a degree of cooling during the expansion. The drills in use are the Granström and Larsson modification of the Rand. The actual drills were originally of the same thickness from end to end, but now they are made to taper off gradually in thickness towards the cutting edge, as these are found to last better, and the long drills are much steadier. At Dannemora all holes are drilled wet, but in the upward holes the injection of the water requires the utilisation of a considerable amount of power, hand injectors being used. If enough water is not used the work done by the drills soon diminishes; the blows become less rapid, and the work entirely ceases. A hard thick ring of tough drill-dust forms round the tool, which stops the drill. In consequence of this, the injection of the water is often harder work than the actual drilling. Every drill remains only fourteen days in use in the mines, and is then taken to the surface to be cleaned and repaired. The work done by the drills varies according to the nature of the country and the position of the hole. The more the direction passes from a downwards to an upwards one, the less is, as a rule, the work done by the drill. Each drill works from $4\frac{1}{2}$ to 5 hours in the day.

J. D. Hay† describes the electrically driven drills at the Rosedale iron ore mines in Yorkshire. Three men are required, and the machine will drill seventeen holes $4\frac{1}{2}$ feet deep per hour in oolitic ironstone. An electro-motor is carried on a trolley, and drives the drill through flexible shafting, the drill itself being supported on a standard. An auxiliary truck supports the shafting and carries the tools, &c.

* *Jernkontorets Annaler*, vol. li. pp. 336-345.

† *Transactions of the Institution of Mining and Metallurgy*, vol. v. pp. 322-333, with one plate.

An illustrated description has appeared* of the François air compressor and rock drills shown at the Brussels Exhibition.

At the visit to the Carn Brea Mine made by the Cornish scientific societies, at their fifth annual joint meeting, experiments were made with rock-drills, different air pressures being employed. In five minutes, with a pressure of 40 lbs. to the inch, the drill pierced 20 inches of good granite; with 60 lbs. pressure, 36 inches of granite was pierced in the same time, and with 80 lbs. as much as 54 inches. The higher pressure therefore gave the best results.†

A Mine Dam.—W. Kelly ‡ describes the construction of a dam built in an exploring drift 6 feet wide and $7\frac{1}{2}$ feet high, to cut off a feeder of water giving about 370 gallons per minute. The sides and roof were sheared back, and an arched masonry dam of stone laid in cement was put in, forming a taper plug 10 feet long and $13\frac{1}{2}$ by $12\frac{3}{4}$ feet in cross section at the back. As this leaked, a 22-inch brick wall was put in 26 inches behind the masonry, and the intervening space filled with concrete. Manure was spread over the back of this wall, and the dam was rendered watertight. A 20-inch manhole pipe and a 5-inch water pipe was laid in. The pressure rose to 277 lbs. per square foot, and the leakage amounted to $2\frac{1}{2}$ gallons per minute. The cost and the details of increase of pressure are given.

Pumping Plant at the Low Field Mine.—Illustrations have appeared§ of a large pumping plant recently erected at the Low Field iron ore mines, near Ulverston. The engine is of the Davey differential type, with high-pressure cylinder 45 inches and low-pressure 80 inches in diameter. The shaft is inclined at 42° , and the length is 1150 feet on the incline, the vertical rise being 735 feet. Two thousand gallons are raised per minute. The main pump is of the single-acting plunger type, connected to the engine by a bell-crank and spear-rods. To equalise the delivery on the indoor and outdoor strokes a subsidiary hollow stationary ram, 17 inches in diameter, is provided. It is connected to a branch on the delivery main, and its casing is movable, being attached to the spears. These are built up of four 11-inch square rods, and carried on cast-iron rollers. The main plunger is $30\frac{1}{2}$ inches

* *Engineering*, vol. lxiv. pp. 289 and 294. † *The Cornishman*, September 30, 1897.

‡ *Transactions of the American Institute of Mining Engineers*, Lake Superior Meeting, July 1897 (advance proof).

§ *Engineer*, vol. lxxxiv. pp. 110, 118.

in diameter, and its stroke is 10 feet. Double-beat valves are provided in duplicate, and one or the other set can be thrown into action by a system of sluice valves.

The Strength of Ladders.—R. G. Brown* gives some particulars of the strength of ladders used underground. The ladders were tested by pulling on the rungs approximately at the angle of a man's arm when ascending, and the results are tabulated. In some cases the rungs broke without warning, and in other cases they were pulled off with loads ranging between 300 lbs. and 1500 lbs. Under ordinary conditions, with a man weighing fourteen stone, the pull and thrust of the hand and foot are taken as 55 lbs. and 166 lbs. respectively, so that some of the ladders showed a factor of safety as low as 2. Wire nails are condemned as being so liable to draw out. The weaker ladder is the very dry one, the most dangerous ladder is the damp one, and the strongest is the new ladder put together with cut nails. In dry places, dry wood with the rungs notched in flush should be used, and for damp places heavier slats should be employed.

Mine Accounts.—J. P. Channing† offers some suggestions on the keeping of mine accounts. These should show accurately the various items of expenditure per unit of production. All expenses are divided under three heads of construction, maintenance and operating expenses, labour and supplies being included under each head, and the question of capital account is also considered. The total number of expense accounts that may be kept is indeterminate, but the following are the principal final divisions:—Exploration, construction, sinking, drifting, raising, stoping, timbering, tramming, hoisting, pumping, stocking, rock-house treatment, loading, general surface expense, railroad transportation, stamping or milling, office, superintendence, insurance and taxes. A form of account sheet for an iron ore mining company is given.

A. G. Charleton‡ gives an outline of a method of opening and keeping a set of mine books, and gives numerous examples of the forms and books employed. The system of cost sheets followed by the author are given.

An exhaustive treatise on mine accounts has recently been written by J. G. Lawn.§

* *Engineering and Mining Journal*, vol. lxiii. p. 602.

† *Engineering Magazine*, vol. xiii. pp. 926-933.

‡ *Transactions of the Institution of Mining and Metallurgy*, vol. v. pp. 243-315.

§ London: C. Griffin & Co., Ltd., 1897.

Mining Law.—H. D. Hoskold * gives some notes on foreign mining laws and adequate areas for mining concessions. In Latin countries the laws are mostly codified, and especial reference is made to the code in force in the Argentine Republic. The dimensions for concessions in that country are given as about 170 and 258 acres for iron ore and coal respectively, and it is held that the former is too great and the latter too small.

An exhaustive memoir has been published by L. Michel † on the relations between the landowners and the mine owners with regard to the inconvenience arising from the use of surface waters.

Leon Michel has published a valuable guide to mining legislation. The subject is dealt with in nine chapters, namely—(1.) Introduction; (2.) Prospecting; (3.) Concessions; (4.) Royalties; (5.) Mine inspection; (6.) Quarries; (7.) Mining law in the French colonies; (8.) Foreign mining law; (9.) Special laws dealing with salt mines, mineral waters, steam-boilers in sanitary works. The volume covers 684 pages.

First Aid in Mining Accidents.—G. W. King ‡ deals with some of the methods to be employed in giving first aid in the case of mining accidents. The several kinds of splints to be used for broken bones are indicated, and the ways of moving the patient are described. Means for arresting hæmorrhage are referred to, and also for counteracting asphyxia. Illustrations of the methods are appended.

Iron Ore Shipment.—J. R. Oldham § gives some particulars of ship-building and transportation on the great American lakes. Illustrations of some of the large steamers for carrying ore are appended. A table has been published || showing dimensions and particulars of the ore docks on these lakes. Amongst the details are length, width, height, number and capacity of pockets, angle of the bottom of the pockets, and length of spouts. The storage capacity amounts to 617,250 tons.

H. V. Winchell ¶ gives some photographic views of the docks and ore pockets at Two Harbours, Minnesota.

* *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 160-173.

† *Bulletin de la Société de l'Industrie Minérale*, vol. x. pp. 725-773.

‡ *Engineering and Mining Journal*, vol. lxiv. pp. 245-247.

§ *Cassier's Magazine*, vol. xii. pp. 499-512.

¶ *Iron Age*, vol. lx., No. 6, p. 12; *Transactions of the American Institute of Mining Engineers*, Lake Superior Meeting (advance proof).

¶ *Engineering Magazine*, vol. xiii. pp. 884-895.

Wire Ropeways.—W. Carrington * considers the various purposes to which various types of wire ropeways now in use are most suitable, and points out the necessity of a selection of the type of ropeway for each variety of work which it is required to do; and for this purpose he describes examples of each type of ropeway, pointing out in connection with each the special situation and circumstances under which it ought to be used, and illustrating it by some example in use which supports the views which he holds. No one system of ropeway can be universally adaptable. The circumstances which should decide as to the type of ropeway to be used are many, chiefly the character of the country which has to be traversed, the class of materials to be transported, and the manner in which such material can be packed, the motive power available, the incline to be surmounted and the spans to be crossed, the quantity to be carried per day, &c.

Five different systems may be adopted, viz :—

(1.) The endless-running rope, as originally made by Charles Hodgson, but greatly improved in all details.

(2.) An endless-rope type of ropeway, with the carriers rigidly fixed in position on the rope.

(3.) The fixed-rope type, also patented by C. Hodgson, but with many improvements and alterations, differing in some details from those made in Germany.

(4.) The single fixed-rope type, in which one carrier is drawn to and fro by means of an endless hauling-rope.

(5.) The use of two fixed ropes, with an endless hauling-rope, in which one carrier travels in one direction while the other runs on a parallel rope in the opposite direction. This type of tramway, of course, is not new, but it has been improved and altered in many ways, and it is now a thoroughly serviceable type of tramway, capable of being used over extremely long spans, and of carrying loads up to two tons.

Examples of each of these are given. In the discussion that followed the reading of the paper reference was made by B. H. Brough and by R. E. Commans to the Otto wire ropeway. The former submitted a reproduction of an old engraving showing an endless ropeway at work in 1641, and referred to the papers by J. Pohlig † and W. Gill. ‡

* *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 91–106, with illustrations.

† *Journal of the Iron and Steel Institute*, 1890, No. II. p. 612.

‡ *Ibid.*, 1896, No. II. p. 36.

III.—MECHANICAL PREPARATION.

Magnetic Concentration of Iron Ore.—Discussing the recent progress in ore dressing, R. H. Richards * describes the magnetic concentration of the soft Clinton red fossiliferous iron ore. The machine used was the Wetherill magnetic concentrator of the inclined pattern. The ore treated was crushed through 15-mesh, and that portion which rested on 40-mesh was used for magnetic concentration. The portion which passed through 40-mesh contained 49·4 per cent. of iron, and was considered sufficiently rich. The material through 15 on 40-mesh was subjected to three consecutive treatments—with 10, with 8, and with 6 ampères respectively. The heads of the 10 ampères went to the 8. The heads of the 8 ampères went to the 6. The tailings of the 8 and 6 ampère treatments are called final middlings, and the tailings of the 10 ampère treatment are called final tailings in the table.

	Weight.	Iron.	Insoluble.
	Per Cent.	Per Cent.	Per Cent.
Raw ore	100·0	39·20	40·16
10 ampère	59·3	54·10	18·80
8 ampère	55·0	54·10	18·70
6 ampère	52·4	56·40	17·10
Middlings	6·9	38·85	41·35
Tailings	40·7	16·70	74·10

The shrinkage in weight by the 8 and 6 ampère treatments lowered the value more than the increased percentage of iron gained, and hence it was decided that the single 10-ampère treatment was the best commercial method. The hard Clinton ore was treated with almost similar results.

The Edison Magnetic Concentrating Plant.—An illustrated description † has appeared of the magnetic concentration plant at Edison, which presents many novel features in the crushers and arrangement of plant. The whole of the run of the mine is crushed down without intermediate screening to pass a fourteen mesh sieve before it is treated magnetically, very large crushing rolls being used in the first instance, and subsequently three-high rolls of a type somewhat similar to those used in certain flour mills.

* *The Mineral Industry*, vol. v. pp. 705-732.

† *Iron Age*, vol. lx. No. 18, pp. 1-8.

The deposit of ore worked is one of those discovered between the St. Lawrence and the Potomac by exploration with the magnetic needle, and consists of a poor magnetite averaging about 20 per cent. of iron. It is worked open cast, being blasted down by a series of holes 2 inches in diameter, 8 feet apart, 12 feet behind the bank, and 20 feet deep. The broken ore is removed by a large steam shovel, and loaded into trucks running on a V-shaped track, arranged to give a constant supply of empties. It is intended to increase the drilling plant, and to introduce an overhead wire cable for shifting the drills. In getting the ore the amount of explosive used is limited, and the crushing machinery is relied upon for breaking up the rock, which may be received in masses up to five tons in weight.

The loaded trucks come into the crusher-house on both sides of the giant rolls, and are handled by two 10-ton cranes of 40 foot span. These rolls are 6 feet in diameter, are 7 feet $3\frac{1}{2}$ inches apart from centre to centre, and have a 6-foot face. The latter is covered with a series of chilled iron plates bolted to the rolls. Projecting from the plates are two series of 2-inch knobs on each plate. Each of the giant rolls, however, has two rows, one diametrically opposite the other, of knobs which project 4 inches. These strike the rock which is dropped between the rolls a series of hammer blows. The rolls, driven by belting up to a circumferential speed of about 3500 feet, the moving parts weighing seventy tons, and the fly-wheel action with intermittent charging is depended upon to break up the rock. The crushed rock drops directly upon a second set of belt-driven rolls, called the "intermediate rolls," underneath the giant rolls. These rolls are 4 feet in diameter, with 5 feet face, the latter being equipped with knobs in the same way. These rolls are placed 4 feet $7\frac{1}{2}$ inches apart from centre to centre, and the capacity of the rolls is 300 tons per hour. The engine which drives the rolls and the other crushing machinery which forms part of this mill is a horizontal compound engine, rated at 700-horse power, using steam at 150 lbs. pressure, supplied by two boilers of the Climax type.

From the giant rolls the rock is elevated by bucket conveyor, and passes through two sets of 36-inch rolls, whose face, 36 inches, is lined with corrugated chilled iron plates, the rolls being placed 39 and $37\frac{1}{2}$ inches apart from centre to centre. These rolls are positively driven, the gears, as is the case throughout the whole plant, being encased and running in oil. The roll shaft and the driving shaft are connected by a safety breaking device. A third set of rolls, 24 inches

in diameter and 20 inches face, reduce the material down to $\frac{1}{2}$ inch size and less. An elevator carries the crushed ore to the dryer, which consists of a tower 9 feet square, 50 feet high, fitted with a series of cast-iron plates 9 feet long and 7 inches wide, arranged alternately at an angle of 45° . The dryer is fired direct. Dried ore is conveyed to a stock-house with a capacity of 16,000 tons, and then brought to bins above the three-high rolls in the concentrating building proper. The machine consists of three rolls 36 inches in diameter by 30 inches face. The centre one is mounted in bearings which are rigidly secured to the housing in the usual way. The lower roll is driven from the main shaft through a wobbler provided with the safety breaking bolts. The upper and lower rolls are free to move in guides formed in each side of the housing. Each end of the roll is provided with a cylindrical sleeve formed with seven grooves for an endless $\frac{1}{2}$ -inch wire rope, which is tightened by a separate pulley carried by a pneumatic cylinder. The pressure of the rolls can thus be adjusted, and direct bearings are dispensed with. The ore is delivered between the upper and middle rolls, and goes from thence between the middle and lower rolls. The rolls themselves are soft iron shells, the practice being to maintain their efficiency by frequent turning by an ordinary tool carriage mounted upon a bridge attached to the housing. The plant consists of four sets of these three-high rolls, of which two are used for the crushed ore from the stock-house and two for handling intermediate products from the concentrating mill.

From the three-high rolls the crushed ore is carried by a conveyor to an elevator, which delivers it to 14-mesh screens, which consist of screen plates placed alternately at 45° in opposite directions. The coarse material goes back to the three-high rolls.

Ore screened through a 14-mesh screen is delivered to what is known as the 12-inch magnets, there being a series of three of them. From these magnets concentrates carrying about 40 per cent. of iron are delivered, while the tailings go to the waste heap, and assay about 1 per cent. in iron. The concentrates which are obtained from the 12-inch magnets are delivered to a dryer, 6 feet square and 50 feet high, fired direct. The dried ore is crushed in the three-high rolls, the product being passed over 50-mesh stationary screens, five in a set, the number of sets being ten. The coarse material which fails to pass the screens is returned to the rolls for regrinding. The fines go to the 8-inch magnets, of which three in series constitute a set, the total number of sets being thirty-two. These magnets deliver con-

concentrates carrying about 60 per cent. of iron, whose further treatment will be described later. The concentrates from the 8-inch magnets are treated to reduce the phosphorus by blowing a current of air through a descending sheet of the concentrates so as to remove the lighter apatite. The dusting chambers, of which there are three, produce cleaned concentrates and dust. The latter is treated on magnets called dusting-machines, which yield a fine dust which is sold for paint, and final concentrates which go to the stock-house. The dephosphorised concentrates are delivered to the last series of magnets, the 4-inch, which are mounted double. Of these, five magnets constitute a series, there being in all sixty-four sets. The products are final concentrates and tailings, the latter being returned to the other end of the mill and recrushed until all gangue is eliminated. All the concentrates are carried by conveyors to the stock-houses Nos. 2 and 3, which hold respectively 5000 and 30,000 tons.

Particulars are given of the size and arrangement of the magnets, and of the current used for exciting them. A scheme of the whole process is given, and particulars are also given of the lubrication and of the means for protecting the bearings from dust.

From the stock-house the concentrates are carried by a belt-conveyor to the mixing-house, where they are delivered to three heated mixers, consisting of horizontal troughs in which two shafts equipped with a series of cutting blades are mounted. One-third of the binding material is added to the concentrates at the point where they are charged. The other two-thirds of the binding materials is distributed at intervals to the charge along the greater part of the mixer trough. By a belt-conveyor the prepared concentrates are carried from the mixers to a scraper-conveyor which runs between a long line of briquetting machines, fifteen on each side. The machine consists of a rotating die-block, 24 inches in diameter and 6 inches face, carrying sixteen dies in which the briquettes are to be formed. Oil injected by a jet of compressed air is successfully used for keeping the dies clean. A pressure of 60,000 lbs. is given to the dies by toggles, and sixty briquettes per minute are made, each measuring 3 inches in diameter, and $1\frac{1}{2}$ inch in thickness, and weighing 19 ounces each. These are carried by a conveyor through chambers 22 feet high and 18 feet long, where they are baked for sixty-nine minutes at 400° to 500° F. There are fifteen chambers, one for each pair of presses. The finished briquettes ready for loading are waterproof, and average as follows :—

	Per Cent.
Iron	67 to 68
Silica	2 to 3
Alumina	0·4 to 0·8
Manganese	0·05 to 0·10
Lime, magnesia, and sulphur	trace
Phosphorus	0·028 to 0·033
Resinous binder	0·75
Moisture	none

A blast-furnace test made with 25 to 100 per cent. of these briquettes, and lasting a week, has been made. The yield of iron was increased, and the consumption of flux and fuel diminished.

REFRACTORY MATERIALS.

Drying Fireclay in Large Masses.—F. Toldt* describes a new clay-drying furnace. He observes that clay can only be properly dried if an adequate quantity of air is brought in contact with it, and that in places where a free circulation of air does not exist, even high temperatures will not be effective, though otherwise the higher the temperature the more moisture can air take up. Thus the cubic metre of air saturated with moisture contains 17·1 grammes of water at 20° C., while at 50° it contains 82·3 grammes, and at 100° as much as 589·5 grammes. He discusses the points on which the drying of clay is dependent, and then describes and illustrates a new furnace for this purpose. He refers in particular to fireclay.

Fireclay in Colorado.—According to H. Ries,† fireclays and pottery clays in Colorado occur in close association, and interbedded with the Dakota sandstones in the hog-backs extending along the eastern edge of the mountains. The fireclay is generally represented by a dark grey or black fine-grained, shaly clay, which is extensively mined at Golden, and has also been worked at Parkdale, and still more recently at Delhi. The fireclay bed at Golden is 12 to 18 feet thick, and often faulted. About one-half of the stratum has to be rejected, as it contains too much iron, but the other half makes excellent firebrick and smaller refractory articles for assayers' use. The Parkdale fireclay beds are on the average 4 feet thick, and more siliceous than those at Golden. Four firms produce firebricks, and the smaller assayers' goods are made by two companies, one at Denver, the other at Pueblo. The following table of analyses, taken from Part IV. of the 16th Annual Report of the United States Geological Survey, will serve to show the composition of several of the better grades of Colorado clays:—

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 387-391, twelve illustrations.

† *Transactions of the American Institute of Mining Engineers*, Lake Superior Meeting, July 1897 (advance proof).

	1.	2.	3.	4.	5.	6.
Moisture	0·47	1·36	...	...	...	3·75
Silica	46·61	63·26	46·88	71·81	56·41	61·00
Alumina	37·20	24·72	35·42	15·09	26·37	35·00
Ferric oxide	0·15	0·43	1·74 _a	1·75 _a	...	0·25
Lime	0·44	0·30	0·44	0·14	0·29	...
Magnesia	0·25	0·13	0·20	0·05	0·20	...
Alkalies	1·23	trace	1·19	1·02	1·55	...
Water	13·65	8·63	14·10 _b	10·14 _b	14·66 _b	...
Organic matter . . . . .	...	0·40	...	...	...	...
Titanic acid . . . . .	...	0·68	...	...	...	...
	100·00	99·91	99·97	100·00	99·48	100·00
Total fluxes	2·07	0·86	3·57	2·96	2·04	...

1. Edgemont, Jefferson County. 2. Pueblo, Pueblo County. 3. Golden, Jefferson County. 4. Crucible clay, Golden, Jefferson County. 5. Kaolin, Golden, Jefferson County. 6. Pueblo, Pueblo County. *a.* Determined as ferrous oxide. *b.* This includes moisture.

Fireclay in Missouri.—C. R. Keyes * gives some notes on the clays of Missouri, and adds the following analyses of fireclays worked in the State :—

Specific gravity	2·47	2·13	2·45	2·43
Combined silica	31·39	26·03	43·56	42·60
Free silica	29·38	37·25		
Alumina	23·56	21·16	41·48	41·88
Combined water	9·25	8·94	14·05	14·00
Titanic acid	0·96	1·07	...	...
Ferric oxide	4·69	1·81	0·35	0·62
Ferrous oxide	0·47	0·82	...	...
Lime	0·55	0·61	0·45	0·28
Magnesia	0·15	0·30	...	0·20
Potash	0·92	0·51	0·20	0·54
Soda	0·08	...		
Sulphur	0·09	0·12	...	...
Sulphuric acid	0·35	0·56	...	...
Total	101·84	99·18	100·99	100·12

The first is a plastic fireclay from the Cheltenham seam in St. Louis county, and the second is the washed pot-clay of the same seam. The others are non-plastic or "flint" clays from Warren and Franklin counties. Fireclays are extensively worked in the State.

The Origin of Dolomite.—R. Hasselblatt † observes that from a consideration of the different occurrences of dolomite in the Caucasus

* *The Mineral Industry*, vol. v. pp. 131-133.

† *Chemiker Zeitung*, vol. xxi. p. 714.

it is evident that its origin must have been of a very varied character. Dolomite is sometimes found in the very thinnest of layers, from the thickness of that of a sheet of notepaper up to a foot, interbedded between talc slate of a silky lustre and magnesite, these various beds repeating themselves frequently and having talc slate as their roof and sandstone beneath them. All these thin beds are, as far as the author knows, of similar thickness throughout their length, and he considers them of a primary character. Then there are large deposits of dolomite occurring in large masses, and promising a composition agreeing almost exactly with the chemical formula, and with only some silica, ferrous oxide, and alumina. A gradual change to limestone has not been observed in these deposits. This dolomite is in part bedded, but it does not, as in the case first mentioned, form beds intercalated with other strata. Its bedded deposits are each some yards in thickness, and are enclosed in mica schist and limestones.

A third kind shows the passage of limestone into dolomite, the materials examined having shown either from 0·1 to 8 per cent. of magnesia, or from 16 to 18 per cent. The intermediary percentage, 8 to 16, has not yet been met with. This dolomite may be considered as of secondary origin, there being no signs of bedding. It lies between limestones and quartzites.

Hungarian Dolomite.—According to Springorum,* the dolomite found near Armónis, on the Temesvar-Orsova line of railway, is coarsely crystalline in structure, and has the following percentage composition:—Silica, 5·00; ferric oxide and alumina, 1·10; lime, 30·5; magnesia, 17·96; loss on ignition, 45·44.

It sinters only with difficulty, and as regards this characteristic closely resembles pure magnesite. At Resicza it was first burnt in reverberatories, and subsequently in shaft furnaces, when if the temperature was adequate, it became black and hard. At low temperatures the colour is yellow, and the material itself can be broken up easily into crystalline granules. Ground and mixed with tar, it was formerly stamped into furnaces for bottoms, but the work was unsatisfactory and disagreeable. Katzelt was the first to show that unburnt dolomite could be used for fettling a furnace, and even for stemming the tap-hole. The dolomite is ground and sifted so that no particle is larger than 0·16 inch. It is moistened with water before use. Tar is not required at all.

* *Stahl und Eisen*, vol. xvii. p. 625.

Hungarian Magnesite.—Near Jolsvar, in Hungary, there exist deposits of magnesite belonging to a Budapest company. At present only the raw magnesite is being produced. Analysis gave the following results:—

MgCO ₃ .	CaCO ₃ .	FeO.	Al ₂ O ₃ .	SiO ₂ .
94·8	0·1	3·2	1·1	0·3

It is intended to produce from this magnesite bricks as well as other products.*

Bauxite.—No change of any import took place in the bauxite industry during 1896.†

F. Laur‡ describes the extraction of aluminates from bauxite. The method of manufacture comprises nine principal operations—(1) Comminution of the bauxite; (2) mixing with carbonate of soda; (3) formation of crude aluminate in the furnace; (4) washing the crude aluminate; (5) desiccation of the ochre residue and formation of liquors of soluble aluminates; (6) carbonation of the aluminate liquors; (7) separation of the alumina by exposure to the air; (8) drying the alumina; and (9) treatment of the carbonate of soda liquors.

A. Liebrich§ discusses the formation of bauxite.

Graphite.—Graphite to the amount of about 13,000 metric tons was produced during 1895 in Bohemia, chiefly from the deposits at Schwarzbach and Mugrau, whilst Upper Styria, Moravia, and the Duchy of Austria made up this to a total of 28,443 tons in 1895. In the same year Ceylon yielded 13,711 tons, Canada 199 tons, Germany 3751 tons, Great Britain 41 tons, Italy 2657 tons, and the United States 349 tons—making a total of 48,973 tons. The American graphite came from Ticonderoga and from Rhode Island, the former being pure and the latter impure, one mine yielding graphite containing 40 to 65 per cent. of carbon.||

F. Kretschmer¶ gives a detailed description of the graphite deposits of Mährisch-Altschadt.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 371 and p. 400.

† *The Mineral Industry*, vol. v. pp. 50–51.

‡ *Bulletin de la Société de l'Industrie Minérale*, vol. x. pp. 823–853.

§ *Zeitschrift für praktische Geologie*, 1897, pp. 212–214.

|| *The Mineral Industry*, vol. v. p. 325.

¶ *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlvii. pp 21–56.

Chromite at Port-au-Port Bay, Newfoundland.—G. W. Maynard* describes the deposit of chromite which occurs at Port-au-Port Bay in Newfoundland. The country is diorite, traversed by serpentine, in which the chromite is found in large angular masses. Analyses show 39 to 50 per cent. of chromic oxide, and experiments have been made on a sample of over 2 tons with a view of concentrating the ore. It was passed through a Blake crusher and Cornish rolls, then through a 20-inch sieve, and thence to a hydraulic classifier, from which a finished product was obtained, the overflow going to Harz jigs and Frue vanners, and the tails finally passing on to a revolving slime table. The dressed products yielded 55.30 per cent. of chromic oxide. A plant is designed for handling 50 tons of crude ore daily.

Chrome Iron Ore in Canada.—In 1895 there were shipped 2837 tons of chromite from the township of Coleraine, and other points on the Quebec Central Railway, and in the following year 2037 tons. Typical analyses of chromite are as follows: †—

Silica	7.00	5.22	6.44 *
Chromic oxide	39.15	51.03	53.07
Ferrous oxide	27.12	13.06	15.27
Magnesia	16.11	16.32	16.08
Lime	3.41	2.61	1.20
Alumina	7.00	12.16	8.01

M. Penhale ‡ states that the ore in Coleraine exists in pockets, many of which have been worked out, but it is stated that several new outcrops have been found in this district. The largest deposit is the Leonard Mine at Lake St. Francis, but the ore is poor.

* *Transactions of the American Institute of Mining Engineers*, Chicago Meeting, 1897 (advance proof).

† *The Canadian Mining Manual*, 1897, pp. 341-342.

‡ *The Mineral Industry*, vol. v. p. 124.

FUEL.

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I.—CALORIFIC VALUE.

Calorimetric Measurements.—L. C. Wolff* discusses the question of calorimetric measurements. The empirical formulæ are first dealt with, and the author observes that the following has been adopted by the Verein deutscher Ingenieure and the International Verband der Dampfkessel-Ueberwachungsvereine, and is generally known as the "Verbands" Formula. In this formula 600 calories are subtracted for every kilogramme of hygroscopic water (W) which is evaporated in the fire and passes into the stack. The formula is as follows:—

$$\text{Calorific power} = 8000 C + 29,000 \left(H - \frac{O}{8} \right) + 2500 S - 600 W.$$

The variations existing between the actual calorimetric measurements and the values as determined from analysis by the Dulong formula are as follows:—

	Per Cent.
Coal	plus or minus 2
Brown coal	" " 5
Peat	" " 8
Wood	" " 12

In the case of pure cellulose, the Dulong formula only shows 3552 calories, while from actual determination it is found to amount to as much as 3855 calories, a difference of 7·9 per cent.

Dealing next with actual calorimetric measurements, the author

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. pp. 763-768.

describes the Berthelot bomb calorimeter, with the Mahler modification and the Stohlmann improvements. The Krøcker modification of the Mahler bomb is also described and its value discussed. An account is given of its use side by side with a Mahler calorimeter, and both have been in constant use at the laboratory of the Magdeburg Verein. Full details are given of a joint test of a fuel by these two calorimeters, the various measurements and calculations being shown side by side in tabular form.

D. Mendeléeff* gives the following modification of Dulong's formula for the heat of combustion of coal:—

$$\phi = 81C + 300H - 26(O - S).$$

The constant 300 instead of 345 is taken for hydrogen to allow for that element being in a solid and not in a gaseous state. It is founded on determinations made on cellulose and various kinds of coals. The formula represents within an accuracy of 1 to 2 per cent. the heat of combustion of pure charcoal, coke, coals, lignite, wood, cellulose, and naphtha fuels.

C. L. Norton† describes a new form of calorimeter designed by himself. It is constructed as follows: An outer water-jacket protects the calorimeter proper from radiation losses. The calorimeter is cylindrical in form, being about 12 centimetres in diameter and 15 centimetres high. It has a loosely fitting cover, with holes for the inlet and outlet gas tubes, and for the ignition wire. The calorimeter is separated from the jacket by an air space. A rotary stirrer is placed near the side of the calorimeter, which holds about 100 grammes of water. The combustion chamber is supported on three legs in the centre of the calorimeter, and consists of a cylinder with its axis vertical. Its diameter is 5 centimetres, and its height 7 centimetres. The top is a tight screw cover, having at its centre a glass window protected by mica. The bottom is hemispherical. The inlet and outlet oxygen tubes are each about 5 millimetres in diameter. The products of combustion on leaving the chamber pass into a flat box with a spiral partition, and then into a helical coil of tubing about 3 metres in length, and finally escape at the top into the air. The tube for supplying oxygen ends at the centre of the chamber. All parts of the chamber and tubing are of copper nickel-plated. The

* *Journal of the Russian Chemical and Physical Society*, vol. xxix. p. 144; *Nature*, vol. lvi. p. 186; *American Journal of Science*, vol. iv. pp. 319-320.

† Paper read before the American Association for the Advancement of Science, through *Industries and Iron*, vol. xxiii. pp. 240-241.

walls of the chamber itself are about 1 millimetre thick, and are gold-plated inside. A platinum crucible, with a hole in the centre of the bottom, is slipped over the end of the supply tube in the centre of the combustion chamber. At about half its height the crucible is divided horizontally by a removable disc of platinum. This disc has a great number of fine holes near its edge, but it is not perforated near the centre. Upon the centre of this plate the sample of coal to be burned is placed. A tight cover perforated with many fine holes is made of platinum somewhat thinner than the crucible walls. The upper parts of the crucible walls are perforated with fine holes. A fine platinum wire heated by a current serves as a fuse. It is insulated from the crucible by mica washers, and ends in stout terminals in the walls of the combustion chambers. These are insulated by mica and leather washers. The manipulation of the apparatus is described.

Baron H. von Jüptner* again discusses the determination of the calorific power of coals by means of the Mahler calorimeter, and by using Jüptner's empiric formula. He deals at length with a paper by N. W. Lord and F. Haas, whose results are tabulated. Baron von Jüptner has already described a simple and rapid method for the determination of the calorific value of a coal, and this he again states as follows:—Find the percentage of moisture, W , in the coal; the yield of volatile matters, G ; the fixed carbon-coke, K , and the percentage of ash, A , in the crucible; and the amount of oxygen S required, by the Berthier method. The calculation is then as follows:—For the combustion of the fixed carbon is required the oxygen quantity $S' = \frac{8}{3}K$; for the combustion of the volatile products the quantity of oxygen $S'' = S - S' = S - \frac{8}{3}K$; the ratio of the oxygen required by the volatile matters to that required by the fixed carbon is—

$$\frac{S''}{S'} = \frac{S - \frac{8}{3}K}{\frac{8}{3}K} = \frac{\frac{3}{8}S - K}{K}$$

Placing the calorific power of the coke carbon at 8000 instead of the number 7630 formerly proposed, and taking C as representing the variable calorific power of the volatile products of distillation, the calorific power of a coal is represented by the formula:—

$$p = 80K + C \frac{S''}{100}$$

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 457–460.

The values of C are as follows for bituminous coals :—

$\frac{S''}{S'}$	C.	$\frac{S''}{S'}$	C.
0.2	4000	3.0	3180
0.3	4000	3.5	3170
0.4	4000	4.0	3150
0.5	3550	4.5	3140
0.6	3400	5.0	3130
0.7	3340	5.5	3120
0.8	3300	6.0	3110
0.9	3270	6.5	3080
1.0	3250	7.0	3070
1.5	3225	7.5	3060
2.0	3210	8.0	3050
2.5	3200		

The calorific power of sulphur is to be taken as 2500.

The author shows that the results obtained by this method of calculation are in satisfactory agreement with those obtained by the calorimetric method of measurement. The results obtained by the aid of the Mahler calorimeter by N. W. Lord and F. Haas are shown in detail, and the result as calculated by the Jüptner method is shown for the sake of comparison in each case. The percentage difference is not more than 0.5 per cent. in seventeen cases, and in only 11 it is 1 per cent. or more, but in no case does it exceed 2 per cent. In all, thirty-four comparative results are shown. A series of other calculations connected with this method of calculation are also shown.

In order to obtain useful results as to the heating effect of fuels by means of the calorimetric bomb, it is necessary, K. Kroeker* states, to determine the amount of water formed by the combustion. This may be readily done and with sufficient accuracy by providing the bomb with two passages through the top by means of which a current of air may be passed through the instrument at the close of a combustion, and the water which has been formed weighed in the usual manner. Experiments made with pure sugar show that this can be done even in the presence of such amounts of sulphuric acid as might be formed by the combustion of coal.

Heating Value of Coal.—C. R. Richards† states that corn is largely burnt as fuel in Nebraska. The average heating value of the coal in use in that State is not far from 11,500 British heat units, while the heating value of corn is about 8040 units. On this basis a

* *Deutsche Chemische Gesellschaft. Berichte*, vol. xxx. pp. 605-607.

† *Cassier's Magazine*, vol. xii. pp. 683-686.

table has been computed showing the cost of corn per bushel to equal that of coal selling at different prices.

An acre of land will produce from 40 to 80 bushels of corn, which if burned will yield 22,512,000 to 45,024,000 heat units. Since a ton of good coal will yield 20,000,000 to 26,000,000 heat units, it follows that an acre of ground is capable each year of producing fuel which is equal to from 0·87 or 1·28 to 1·74 or 2·56 tons of coal. The stalk will probably increase this amount by one-fourth.

Kaestner* deals with the preparation and combustion of brown coal. All dry or wet-pressed brown coal briquettes, when properly used, are suitable, he observes, for house or works use. If the raw brown coal is to be burnt on a flat fire-grate, its size, he states, should be from that of "hens' eggs" to a "child's head" size. This is not the right way to burn brown coal though. He illustrates a suitable form of step grate, the success or failure depending on the angle. A step grate which will do excellently for one coal will not be suitable for another. For brown coal the angle is about 32°. The fuel should be of uniform size. Other suitable forms of grate are described.

Pyrometry.—The *Revue Industrielle de l'Est* publishes a paper by Bichat on the measurement of high temperatures. After drawing attention to the multiplicity of phenomena used in the construction of pyrometers, the author classes these apparatus into four distinct categories — (1) optical pyrometers, (2) calorimetric pyrometers, (3) thermo-electric pyrometers, and (4) dilatation pyrometers, and discusses the relative advantages of each.

C. v. Ernst† again discusses the Le Chatelier pyrometer. Referring to Wiborgh's adverse criticism,‡ he points out that this pyrometer has already been introduced at numerous works, where it is constantly employed for the determination of very high temperatures, including iron and steel works, and its use has given general satisfaction. The author discusses the principle on which the pyrometer is based, and describes its construction.

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. p. 403; seven illustrations.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 300-302; one illustration.

‡ *Journal of the Iron and Steel Institute*, 1896, No. II. pp. 294-296.

II.—COAL.

Coal in Yorkshire.—R. Sutcliffe* gives some notes on the Yorkshire coalfields. The structure of the field is briefly described, and mention is made of the several seams which occur.

F. Coultas† describes the geology of Deepcar and its surrounding hills around the Don and Little Don valley. The faults in the district and their connection with the villages are discussed, and the various fireclays and coal-seams worked in the district are mentioned. Sections of the strata are appended.

Coal in South Staffordshire.—The boring for coal at Himley, near Dudley, has proved the existence of carboniferous rocks beyond the limit of the known South Staffordshire field on the western side of the boundary fault. In the event of the present discovery resulting in finding a thick bed of workable coal, it is proposed to put down an extensive colliery plant.‡

Minerals at Netherseal Colliery.—G. J. Binns and G. Harrow§ give a list and analyses of minerals found at the Netherseal Colliery, Leicestershire. The Coal Measures are here overlain by Permian and Triassic rocks, and much faulted. The minerals found are zinc blende, siderite, barytes, galena, and copper pyrites.

The Kent Coalfield.—Professor Boyd Dawkins|| gives the history of the discovery of the south-eastern coalfield, and pays especial attention to his own part in the early stages of the work.

R. Etheridge brought before the Engineering Congress of the Institution of Civil Engineers the subject of the discovery of coal near Dover.

E. A. Martin¶ also shortly describes the section shown in the Dover boring, and mentions some of the fossils.

* *Transactions of the Manchester Geological Society*, vol. xxv. pp. 246-255.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 341-347, with map.

‡ *Colliery Guardian*, vol. lxxiv. p. 568.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 252-255.

|| *Transactions of the Manchester Geological Society*, vol. xxv. pp. 155-163.

¶ *Science Gossip*, vol. iv. (New Series), pp. 157-160.

Exploratory boreholes for coal are being sunk in Kent, the first of these being in the parish of Barham,* between Dover and Canterbury.

A photographic illustration of the surface works at the Dover sinkings has been published.† At that time (July 24) the Brady pit had reached a depth of 420 feet.

The Grottau Brown Coal Mines.—The Grottau brown coal mines in Northern Bohemia are described by F. Katzer.‡ This coal-field is one of the smallest in Bohemia, and stretches along the Neisse river on the Saxon frontier. Hitherto it has been but little described, but this the author now does in detail.

The Grottau brown coal is undoubtedly fossilized wood. When moist from the mine, it possesses a lignitic earthy appearance, and when dried it shows the distinct structure of the trees from which it originated. The specific gravity of this lignite varies from 1·157 to 1·170, the average being 1·163. Analysis shows it when dried at 110° C. to have the following percentage composition:—

Carbon.	Hydrogen.	Oxygen, Nitrogen, and Undetermined.	Ash.
53·22	5·56	37·95	3·27

It takes fire readily and burns with a very luminous flame. The ash is white. Even cold caustic potash solution is coloured brown by this fuel. Air-dried, the lignite loses 34·2 per cent. of its weight, owing to loss of moisture. This was in the case of a clean piece specially prepared. A sample taken directly from the mine lost 55·3 per cent. of its weight when left some eight weeks in contact with the air of a room. Sulphur is occasionally high. In the only sample in which it was determined 3·84 per cent. was present.

The Cannel Coal of Peterswald.—R. Daniloff§ observes that cannel coal has been found, since Zincken's description of these coals in 1887 and 1888, at the Heinrichsglück Colliery, Peterswald. This discovery has not been hitherto described, and the author therefore publishes an account of it as a kind of appendix to Zincken's papers on this subject. The colliery now in question lies at about the centre of the Ostrau-Karwin district. Beds of sandstone, siliceous

* *The Dover Standard*, October 9, 1897.

† *Ibid.*, July 24, 1897.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 561-564, and 576-579, with sheet of illustrations.

§ *Ibid.*, pp. 467, 468.

slates, and clay slates are met with, and between these are seams of coal varying in size from the thinnest of partings to seams upwards of two yards in thickness. The Carboniferous beds are overlain by Tertiary beds and recent deposits. A fault throws the seam about 60 yards, the northern part of the basin being raised about 60 yards as compared with the southern half. It is in the southern half that the cannel coal is found. The seam varies in thickness from 4 feet 3 inches to 6 feet 10 inches, and is either horizontal or has a dip not exceeding 20° . In the clay slates forming the roof of the cannel seam remains of flora and fauna are not met with. Below the seam is sandstone, and in this such remains occur, sigillaria being abundant. The cannel coal is at its maximum thickness in the vicinity of the fault, but gradually thins out in all directions, its place being taken by bituminous coal. The cannel has a grey to velvet-black colour and a brownish-black lustreless streak, a fracture which is almost flat-surfaced, low specific gravity, and possesses much toughness. It can readily be turned and polished. It will burn readily, and is, the author observes, a true "candle" coal. The author thinks that, like all other coals, cannel coal is of vegetable origin, but he considers that the plants from which this seam originated were richer in germs and similar organisms, and that the bitumen did not originate in organic remains. No remains of fauna are found in this seam.

Coal in Hungary.—J. H. Kloos* describes the coalfields of Fünfkirchen in Southern Hungary and in the Banat.

Coal in Belgium.—J. Smeysters† has published an exhaustive memoir on the general map of the Belgian mines and the plans of the coalfields of the Centre, Charleroi, and the Basse-Sambre, shown at the Brussels Exhibition. Illustrated by means of seven large folding plates, this memoir throws much light on the structure of the Belgian coalfields, and tends to dissipate the fears frequently expressed with regard to their premature exhaustion.

Coal in France and Belgium.—P. Schneider and G. Le Bel‡ describe generally and briefly the coal-bearing districts of France and Belgium, showing where the different kinds of coal are chiefly found,

* *Zeitschrift für praktische Geologie*, 1897, pp. 148-156.

† *Annales des Mines de Belgique*, vol. ii. pp. 537-561.

‡ *The Mineral Industry*, vol. v. pp. 166-178.

and giving in diagrams the productions of the several districts during the last twenty or thirty years. The statistics are also given in tabular form to show the production, number of workpeople, costs, accidents, &c.

Coal from the Gard, France.—M. Coignard * gives the following results of assays of coal from the Gard :—

District.	Volatile Matter.	Ash.
	Per Cent.	Per Cent.
Bordezac	18.50	...
Beaùges	23.10	16.30
Bordezac	21.10	20.60
Bordezac	25.70	14.10
Bordezac	21.20	9.10
Cessous	7.60	11.50

The Rhenish Brown Coal Industry.—C. Schott † observes that the Rhenish brown coal is chiefly employed in the manufacture of briquettes. The district in which workable seams of brown coal are found extends, in Tertiary rocks, for 15 miles in length, with an average breadth of rather over 3 miles. The average thickness of the over-burden is some 11 to 17 yards, and the average thickness of the seam some 98 feet. It is estimated that the available amount of brown coal in this field amounts to 3600 million tons. At the present time there are twenty active mining companies working this deposit, open workings being solely employed, the annual output being about 2,000,000 tons. The fine raw material is dried, heated, and compressed into briquettes under a pressure of about 200 atmospheres, the bitumen of the brown coal acting as a self-binding agent for the fuel. Given a proper grate, the raw brown coal will evaporate the same amount of water per square yard of boiler surface as ordinary bituminous coal, while it does not slag, and admits, too, of cheaper labour charges. At the present time the annual output of briquettes is some 600,000 tons, 70 presses being in use in 14 works.

Coal in Prussia.—Announcement is made by Von Rosenberg-Lipinsky ‡ of a new discovery of brown coal in the province of Posen, at Stopka, 12 miles north of Bromberg.

* *Annales des Mines*, vol. xii. p. 90. † *Stahl und Eisen*, vol. xvii. p. 464.

‡ *Zeitschrift für praktische Geologie*, 1897, pp. 247-250.

Coal in Alsace.—The Memoirs of the Geological Survey of Alsace-Lorraine announce that Professor Bücking has visited the coal deposits of Diedolshausen, which are met with at the surface, and are of true Carboniferous age. The coal is an anthracitic variety, yielding 63·4 per cent. of carbon, 16·6 per cent. of volatile constituents, and 20 per cent. of ash. The deposit does not appear to be capable of being profitably worked.

The Petzkowitz Collieries.—W. Jicinsky,* discussing the Witkowitz Collieries at Petzkowitz, in Prussian Silesia, observes that the Ostrau coal-basin is a part of the enormous coalfield which stretches from Krzeszowice, near Cracow, through Russian Poland and the whole of the south-eastern portion of Prussian Upper Silesia, and on into Austrian Silesia and Moravia, for a distance, as far as known, of at least 105 miles. The Ostrau seams are the oldest in the field, and are partly of fresh-water and partly of brackish-water origin. For more than a century the outcrop of coal near Petzkowitz has received more or less attention. In 1782 working was commenced on a small scale, and until the thirties in the present century only adit working had been employed. Then a shaft was sunk to a depth of 242 feet, and provided with a steam-engine. The quantity of coal wound through this shaft was at first small, and amounted in the seventies to about 15,000 tons a year. In 1896 the quantity wound was 100,000 tons. The old winding-engine to which reference has been made was kept in use until 1883. The collieries in this neighbourhood now belong to the Witkowitz Company, and the field is now being opened up on a much larger scale than has hitherto been the case. The coal is of the anthracitic type, not yielding much gas, very lustrous, fairly low in ash, and not weathering very readily. Occasionally the coal has been stored for two or three years without deteriorating. Mixed with other coals, a good dense coke is obtainable. The ash varies from 4 to 12 per cent., and averages 6 to 8. The theoretical calorific power of the coal is from 7700 to 8300 calories. The yield of "coke" is from 71 to 80 per cent., or more. The author describes the chief workings. The old Anselm shaft is now 876 feet deep. It is walled, is round, and 14 feet 9 inches in diameter. A section given shows about 115 seams of coal. Of these, 17 vary from 20 inches to 49 inches, and may be considered as being thick enough to admit of their

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 205-210, with sheet of illustrations.

being mined with commercial success. The author discusses the question of the further opening up of the field.

Coal in Saxony.—K. E. Weigel * describes the opening up of new coal-seams at Zwickau, in Saxony.

Coal in Italy.—The *Rassegna Mineraria* † announces the discovery near Saldano and Perinaldo, in Liguria, of a thick deposit of brown coal of excellent quality.

The Russian Coalfields.—For the use of the Geological Congress, which met in Russia in 1897, an extensive series of guides were published, and several of these ‡ deal with the coalfields in that country from a geological point of view. One of the most complete is by Th. Tschernyschew and L. Loutouguin, and contains a full description of the Donetz coal-basin. The district has been mapped on a scale of 1 in 42,000, and the stratigraphy very fully studied. The underlying rocks are of Devonian age, and the overlying strata of Permo-Carboniferous and Permian age. The Carboniferous formation is divided into three groups, and the workable coal-seams occur chiefly in the upper four of the six subdivisions of the middle group, and to a much smaller extent near the base of the top group. A very full list of fossils which occur, and of the kinds of rock in each strata, are given by the authors. In age they are referred to the lower part of the Upper Carboniferous, and they attained their full development in the middle period of that age. The series of beds is very complete, and shows an uninterrupted succession of the flora and fauna. The Ural fields are partly dealt with by Th. Tschernyschew, and S. Nikitin describes the geology of the Moscow coal-basin, in which the middle and lower sections of the Russian Carboniferous system are developed. The former corresponds in age to the mountain limestone, and the coal-bearing formations are at the base of the latter. The coal is of poor quality, approximating to lignite instead of true coal, in spite of its age. The coal industry is in a decaying state.

According to Alekceff, § Russian coal deposits may be divided into two main classes—European and Asiatic. Of the latter, only the coal-basin of Kussnetz, of the Island of Saghalien, that of Semi-

* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1896, pp. 34-64.

† Vol. vii. p. 118.

‡ *Guide des Excursions du VII. Congrès Géologique International*, Nos. xiv., xvi. *Colliery Guardian*, vol. lxxiv. pp. 388, 420, 662.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xvii. p. 307.

palatinsk, and the Turkestan basins are of much importance. The Kussnetz collieries belong to the State, and yield three kinds of coal: that of Belsk, representing smithy coals; the Kaltschugin coals, which are excellent gas-coals; and the Jourin deposit, which yields dry, sandy coals remarkably low in ash, only 0.17 per cent. The Saghalien coals are of high calorific power, and contain only 1.7 to 4.8 per cent. of ash, and only 2 per cent. of moisture. Long-flaming bituminous coal is found here. The Semipalatinsk coals are of less value, and contain much ash. Some anthracite is met with. The Turkestan coals are better, containing but little ash, and only a small quantity of sulphur. Only 600 tons a year is mined, however.

In the Caucasus the whole of the output is from the Kuban and Thibulsk mines. These yield good gas-coals, though they are high in ash, containing some 15 per cent.

With regard to the European coalfields of Russia, small deposits, always mixed with brown coal, are of frequent occurrence. North of Lake Onega are some very small deposits of anthracite, high in ash. The only basins that need consideration are those of Moscow and of Poland, together with the coalfields of the Don and of the Urals. The Moscow coal is very rich in hydrocarbons, but contains much ash and much sulphur. Still it is a coal in much demand and much liked. The Donetz coal competes with this Moscow coal, the first cost of which is considerable. The Dombrowa district in Poland forms a continuation of the Silesia coal-basin, and its coal possesses the good qualities of the Silesian coal, except that it does not yield so good a coke. It contains about 1.2 per cent. of sulphur. The Don district yields a very large number of different kinds of coal, from the most recent brown coal to anthracite, which is found near Groschefska. The Don coal is the most important in all Russia, on account of its nearness to the iron ore deposits and to the Black Sea. Unfortunately, good though the coal is otherwise, it contains from 2.5 to 5 per cent. of sulphur. Its calorific power, however, is higher than that of the Polish coal. The small quantity of coal mined in the Urals consists mainly of anthracite, the best being that from the Bebrov collieries. This anthracite has a calorific power of 8000.

Taken as a whole, Russia is rich in bituminous coals of all kinds, in addition to anthracite, but with the exception of the Moscow, Dombrowa, and Don basins, these coal deposits are still but very little mined. There are, too, very few coke-oven plants in Russia. At present wood is the fuel mostly consumed.

Coal in Poland.—In the Transactions of the St. Petersburg Technical Society, W. J. Müller and A. J. Stepanoff discuss the composition of coal from the Dombrov basin in Poland, showing that it is ill-adapted to the manufacture of coke and gas, and as it will not withstand transport, it can be used only for steam-raising, for smelting, and for household purposes. The British coal imported into Russia is better both as regards the percentage of carbon and as regards the heat-producing power.

Coal in Teruel.—In the province of Teruel, Spain, ore deposits and coal are met with in abundance. Of manganese, the mine worked on the largest scale is La Innocencia, which yields ore containing 60·48 per cent. of the metal. The coal deposits are specially promising. The coal improves in quality as the mines become deeper, a recent assay of coal from the Los Cabecicos mines having yielded 55·85 per cent. of fixed carbon, 9·56 per cent. of moisture, 3·33 per cent. of ash, 31·26 per cent. of volatile constituents, and 1·08 per cent. of sulphur. Its specific gravity is 1·390.*

Coal in Asia Minor.—P. Holtzer † describes the Heraclée (Eregli) coalfield in Asia Minor. There are three divisions, that of Coradons, that of Cozlou, and that of Aladja-Agzi. The Cozlou division, by far the most important, contains twenty-four seams representing a total thickness of 40 yards of coal. Owing to the competition of English coal, and owing to the absence in Turkey of industries consuming coal, the output of the coalfield does not exceed 170,000 tons per annum.

G. Ralli ‡ also describes the geology of this coalfield at some length.

Coal in India.—T. D. La Touche § reports on the occurrence of coal at Palana village in Bikanir State, 13 miles south of Bikanir, in north latitude 27° 51' and east longitude 73° 18'. The coal was found at a depth of 212 feet during the sinking of a well. The age of the coal appears to be nummulitic or Lower Eocene, and to correspond to that of the Salt Range in the Punjab. The coal has a woody texture, and is dark brown in colour, resembling rather the Cretaceous coal of Assam than the nummulitic coal. On assay it shows—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Total.
8·20	42·72	39·28	9·60	100·00

* *Industria Minera* (Linares), vol. iii. No. 50.

† *Bulletin de la Société de l'Industrie Minérale*, vol. x. pp. 773-822.

‡ *Annales de la Société Géologique de Belgique*, vol. xxiii.; *Colliery Guardian*, vol. lxxiv. p. 376.

§ *Records of the Geological Survey of India*, vol. xxx. pp. 122-125.

It disintegrates on exposure, sinters slightly, but does not cake; the ash is light brown, and the evaporative power is 13.58, the calorific power in Centigrade heat units being 7293. Where struck, the coal was 8 feet in thickness, but this was reduced to half at a distance of 10 feet, showing surface erosion. A section of the strata passed through is given.

C. S. Middlemiss* deals with the geology of Hazara and the Black Mountain, and refers to the coal found in the Dore Valley and the neighbouring parts of Hazara. Details have for some time been known of the deposit, which has been worked in a small way. It occurs near the base of the nummulitic limestone, and the thickest exposure of coal and carbonaceous shale is 18 feet. The ash, however, in the top 9 feet averages 46 per cent., and in the lower portion 32 per cent., but the tenth foot from the top is somewhat better, showing—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Total.
5.20	11.80	65.80	17.20	100.00

The bed has been greatly distorted, and is very variable in thickness and character.

Coal in Canada.—The Canadian Mining, Iron and Steel Manual for 1897 contains a large number of illustrations of the surface works of the collieries in that country, and a general review of the coal industry. A general sketch of the geology of the coal districts, and of the occurrence of the coal, is given for Nova Scotia, New Brunswick, Manitoba, and the North-West Territory and British Columbia. Particulars of the various companies are given, often accompanied by a short description of the plant. Some statistical details are also appended.

E. Gilpin† gives some notes on the undeveloped coalfields of Nova Scotia. The various localities at which coal has been found are described, and particulars are given of the seams which occur, the amount of working that has been done, and analyses of the coals as far as they are available. It is considered that the seams may extend much farther than they have been proved up to the present, and that other good seams may be discovered or rendered available.

G. C. Hoffmann,‡ of the Geological Survey of Canada, has assayed

* *Memoirs of the Geological Survey of India*, vol. xxvi. pp. 40-41, 140-142, 287-290.

† *Transactions of the Nova Scotian Institute of Science*, vol. ix. pp. 134-149.

‡ *Annual Report of the Geological Survey of Canada*, vol. viii. ; Report R., p. 18.

a specimen of coal from Sheep Creek Coal Mines, Alberta district, North-West Territory, with the following results:—

	Per Cent.
Moisture	3.08
Volatile constituents	39.37
Fixed carbon	54.50
Ash	3.05

The seam is of Cretaceous age, and is said to average 4 feet in thickness. Experiments have been made on a large scale in the preparation of coke from this coal in a Coppée oven, with very encouraging results. The product is a useful metallurgical coke containing 0.17 per cent. of moisture and 10.7 per cent. of ash.

Coal in South Africa.—Both Matabeleland and Mashonaland have abundant coal resources. The most westerly basin extends to within 100 miles of the Victoria Falls on the Zambesi, and the Carboniferous formation continues almost without intermission to the meridian of Salisbury. The spot nearest to Buluwayo where coal was known to exist was some 150 miles distant (down the Khami river); an ox-waggon service was organised, but was demoralised by the tsetse-fly. Surface specimens of this coal were analysed by Van Ness in Buluwayo, and showed a quality not far short of Welsh steam-coal. The natural point for attack for this region is from Gwelo, a northward spur of tableland (forming the great divide between the Limpopo and Zambesi watersheds) which juts forward from that district almost to the Zambesi, and terminates in an extensive plateau known as the 'Mfungufusi, the geological formation of which is Carboniferous. A tramway route can be constructed here with the utmost facility, for the gradients are most easy, first-class timber is plentiful, and there are no streams to cross; such a tram-line would pass through or close to several mineral belts, and would enable coal to be run down to the Selukwe mines, which are some of the most important in Rhodesia.*

In a presidential address to the Chemical and Metallurgical Society of South Africa on June 17, 1897, C. Butters observed that the coal-fields of the Transvaal are of enormous extent. The ash is high, that of boiler-coal being from 20 to 25 per cent., while the smithy coal contains 10 per cent. No colliery at the present time yields a coal of constant quality. The coke thus far produced is not strong enough

* *South African Mining Journal; Engineering and Mining Journal*, vol. lxiii, 58.

for blast-furnace purposes without admixture with a considerable proportion of foreign coke. The average ash contained in this Transvaal coke is 17·2, whilst the ash contents of the coke imported from the United Kingdom average, according to the author, 11·2 per cent. The cost of the coke is very high, local prices amounting to £2, 10s. to £3 per ton. The quality of the coke made is being gradually improved.

W. T. Hallimond* adduces evidence to show that the Transvaal coal-seams are of subaqueous origin. The geological formation is briefly dealt with in relation to the banket and other deposits.

Two assays of coal from British Central Africa are given by Sir H. H. Johnson in his recent work on that country: †—

Fixed Carbon.	Ash.	Volatile Matter.	Sulphur.	Coke.	Calorific Value.
57·63	15·57	26·80	0·10	73·20	5520
47·46	8·4	44·54	0·52	55·5	6050

The first of these comes from North Nyassaland, and the second from the Songwe River. Both assays were made by W. R. Dunstan at the Imperial Institute.

Coal in Zululand.—According to J. Jervis Gerrard, Acting Commissioner of Mines, ‡ the importance of the coalfields in Zululand has never yet been fully appreciated. The most important coalfields yet discovered are those of St. Lucia and Ntambanana, owing to their proximity to the coast. A scheme is on foot for connecting the St. Lucia fields with Durban—a distance of about 170 miles—by means of an extension of the North Coast Railway, now being constructed to the Tugela River. Consideration is also given to the question of utilising the mouth of the River Umhlatuzi for the shipment of coal by means of lighters to Durban. Coal undoubtedly exists on the coast itself in the vicinity of this river, this being, it is said, the only locality in the whole of Africa where coal is actually known to occur on the coast and in British territory. It is urged that the time has come when some definite action should be taken with regard to this important question.

Coal in Java.—M. Verbeek§ and R. Fennema state that coal of Eocene age is found in Java. It is not, as far as is yet known, of

* *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 372-374.

† *British Central Africa*, p. 51 (London: Methuen & Co.).

‡ *Natal Mercury; The Globe*, July 16, 1897.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 419.

much importance, however. Many of the seams are very thin, and although a seam a yard in thickness exists at Bantam, it is subjected to so much faulting, and the coal is of so poor a quality, that it does not justify the formation of a harbour or the construction of a railway to open up the deposit. The lignite found in the Oligocene and Miocene beds is of still poorer quality.

The Mammoth Coal-Seam.—H. N. Sims* describes a peculiar occurrence in the Mammoth coal-seam near Ashland, Pennsylvania. At the outcrop, for a distance of 2000 feet, the seam is split, so that it shows a double outcrop, and in section forms a kind of Y, and the rocks between the arms form a perfect synclinal, ranging up to 320 feet in breadth.

Coal in the South-Eastern States of North America.—J. Head† gives a general sketch of the coal industry of the south-eastern States of North America. The districts especially described are the Pocahontas and the Big Stone Gap districts in Virginia, the Middlesbrough district, the Jellico district, the Coal Creek district, the Poplar Creek district, the Emory district, the Chatanooga district, all in Tennessee and Kentucky, and the Birmingham district, Alabama. The number and nature of the seams in these fields are given, together with numerous analyses and particulars of the methods and costs of working.

Coal in Virginia.—C. Catlett‡ gives a few particulars of the Kanawha and New River coal districts. The former yields about two million tons, and the latter two and a half million tons yearly. In the Kanawha district the Middle Coal Measures are worked, yielding highly bituminous and non-coking coals. In the New River the Conglomerate Coal Measures are worked, and probably can be correlated with the Flat Top region, where the beds are rather thicker. The seams of this district all make good coke.

Coal in Tennessee.—A photograph is published§ showing the section of the Johns coal-mine belonging to the Tennessee Coal, Iron & Railway Company. This company owns in all twenty-eight

* *Colliery Engineer and Metal Miner*, vol. xvii. p. 532.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 177-192, with maps and sections.

‡ *Engineering and Mining Journal*, vol. lxiv. pp. 153-154.

§ *Ibid.* vol. lxiii. p. 574.

collieries, with an aggregate daily capacity of 16,900 tons, and 3256 coke-ovens, which can turn out 5230 tons daily. The company has signed a contract with the Semet-Solvay Company for the erection at Ensley of a plant for recovering the by-products of coking. The cost is to be £100,000.

Coal in Utah.—According to J. M. Goodwin,* there are several collieries at work in Utah. Some of these are near Scofield, where there is a bituminous seam 24 feet in thickness. The first collieries worked in the State were around Coalville, and renewed attention is being given to this district, which covers a considerable area. The seam is 10 feet thick under 40 feet of sandstone with a soft floor. About a third is waste, but all has to be extracted to avoid spontaneous combustion.

At two places at the eastern base of the Blue Mountain Range in Utah a coal-seam has been opened, and this shows about 2 feet of excellent lignite. The fuel is well adapted for steam-raising. The range is rich in metalliferous deposits.

Coal in Colombia.—The United States Consul at Cartagena reports that coal has been worked in his consular district for six years. The fields comprise 215,000 acres of land, and probably contain 300,000,000 tons of coal. The entire territory is held under a Spanish title or grant by the San Andres Indians, an independent native tribe consisting of not more than 11,000 persons, who have given a lease of the coal lands for a term of forty-eight years. The coal itself appears to be of good quality. The thickness of the seam is from 1 foot to 10 feet. The cost of getting out the coal is given as five shillings per ton. Coal is also found on the coast below Cispata Bay. This is of good quality, anthracite and bituminous, but is at a considerable distance from the principal Columbian ports, and is not worked at present. The principal coalfields are situated in the Department of Bolivar, near the Sinu River, in what is known as the Savannahs, 8 to 12 miles distant from Cispata Bay.

Palæontology of Coal.—B. Renault † has shown, by the aid of photographs, that coal contains considerable quantities of bacteria. The material he examined was coal of French origin, and in which the conversion from the original wood could be plainly detected.

* *Salt Lake Tribune*, through the *American Manufacturer*, vol. ix. p. 373.

† *Comptes Rendus de l'Académie des Sciences*, vol. cxliii. p. 953.

Long chains of micrococcus were found in these between what had been the wood fibres. The author gives them the name of micrococcus carbo, and distinguishes two varieties. In addition, other kinds of bacteria were distinguishable, to one of which the name bacillus carbo is given. Rénault believes that to these is due the conversion of the cellulose of the wood into coal, and not only this, but into the different kinds of coal, according to the extent to which this conversion had been effected before their action ceased.

Molybdenum, Selenium, &c., in Belgian Coal.—According to Armand Jorissen* the brownish-grey flue-dust produced when Liège coal is burnt contains ammonium salts, sulphates, and iron, and in the aqua-regia extract were found traces of selenium, molybdenum, antimony, bismuth, nickel, cobalt, arsenic, copper, lead, zinc, and calcium.

III.—CHARCOAL.

Continuous Carbonising Kiln for Wood.—Based on theoretical considerations and on practical experience, an annular continuous-acting carbonising kiln for wood has been invented by E. J. Ljungberg.† It consists of four or eight chambers. In the first division the wood is decomposed, in the second it is dried, in the third preheated, and in the fourth the charcoal is quenched and drawn out and new wood charged in. The combustible gases formed from the decomposition of the wood are burnt in the second section, whilst in the third not less than 30 per cent. of the water in the wood is driven off. For preheating the wood six days are required, for drying and carbonising five days, and for the complete carbonisation five days more, and for quenching, drawing, and charging four days, making twenty days in all.

A kiln with eight divisions is able to carbonise in the year 6109·8 cubic feet of wood, in 146 divisions, 892,112·5 cubic feet, whereby 647,309·6 cubic feet of charcoal is obtained. The cost of working is only one-third that of charcoal burning in heaps. Up to the present time ten of these kilns are in use, of which eight are in use at Domnarfvet.

* *Annales de la Société géologique de Belgique*, vol. xxiii. pp. 101-105.

† *Jernkontorets Annaler*, vol. lii. pp. 311-328. Drawings of this kiln have been published by B. H. Brough in the *Journal of the Society of Arts*, vol. xlv. p. 73.

Careful experiments made by the author show that a cubic metre of wood charged into the kiln contains :—

Kilogrammes.		Carbon.	Hydrogen.
		Kilogrammes.	Kilogrammes.
267·54	Cellulose	138·05	17·39
186·49	Moisture . . . . .	...	20·72
1·67	Ash . . . . .	...	...
...	Difference . . . . .	...	1·48
455·70	Total	138·05	39·59

The yield was found to be as follows :—

Kilogrammes.		Carbon.	Hydrogen.
		Kilogrammes.	Kilogrammes.
111·00	Charcoal	91·30	4·60
3·40	Tar	2·76	0·37
6·74	Acetic acid	2·69	0·45
2·58	Methyl alcohol	0·96	0·32
1695·93	Volatile gases	40·34	...
304·69	Water . . . . .	...	33·85
...	Total	138·05	39·59

On the other hand, a cubic metre of wood burnt in heaps gave :—

	Carbon.
	Kilogrammes.
Anhydrous charcoal	74·53
Carbon lost	63·52
Total	138·05

This yield of 72·56 volumes per cent. in the kiln and 59·22 per cent. in open heaps shows an increased yield of charcoal of 22·53 per cent. in the case of carbonising in kilns.

IV.—COKE.

Coke-Ovens.—C. E. Bowron * gives a cross section of a double bench of beehive ovens, with a flue for leading waste gases to boilers,

* Report of the Bureau of Labour Statistics and Mines of the State of Tennessee, through the *Colliery Engineer*, vol. xviii. pp. 60-61.

as used at Tracy City, Tennessee, and elsewhere in the Southern United States.

It is stated * that designs are being prepared for a coke-oven 200 feet long, with a moving bottom built up of tubes cooled by water circulation. The coking process is to be continuous.

Seventy-five ovens are being built near Raton, New Mexico. The waste gases are used for firing boilers, from which power is obtained to generate electricity for hauling and driving the machinery. Robinson washers are used.†

Coke in the Southern United States.—According to C. Haller,‡ most of the coke produced in the Southern United States is made in beehive ovens of about six tons capacity, and about a forty-eight hours burning for ordinary coke, or seventy-two hours for the best hard quality of coke. The latter quality, however, only forms about 10 per cent. of the total. The following are average assays of Alabama coke :—

Description.	I.	II.	III.
	Per Cent.	Per Cent.	Per Cent.
Moisture	0·75	0·75	0·75
Volatile combustible matter	0·75	0·75	0·75
Fixed carbon	84·50	88·50	87·00
Ash	14·00	10·00	11·50
Sulphur	0·9 to 1·6	0·8 to 1·1	1·0 to 1·3

The ash contains :—

Description.	I.	II.	III.
	Per Cent.	Per Cent.	Per Cent.
Silica	47·00	45·10	46·00
Ferric oxide	12·46	12·32	12·00
Alumina	33·62	31·60	32·00
Lime	1·50	1·50	1·00
Magnesia	1·69	trace	0·50
Sulphur	0·75	0·50	0·60

Coke No. I. was made from coal just as it comes from the mine, while II. was from washed coal smalls, and III. from lump coal. In good coke, such as II., the volume of the cells amounts to from 45 to

* *American Manufacturer*, vol. lx. p. 733.

† *Engineering and Mining Journal*, vol. lxi. p. 455.

‡ *Stahl und Eisen*, vol. xvii. pp. 441–442.

50 per cent. of the total volume, or, after deducting the ash, about 50 or 60 per cent. The crushing stress is 800 or 1100 lbs. per square inch, whilst the specific gravity of the coke is 0.861, or of the coke substance, free from cellular spaces, that is, 1.784. The yield of coke in the ovens used is at least 60 per cent., and its cost of manufacture 1.52 to 1.55 dollar per ton.

Instead of the ordinary old type of beehive oven, in which the combustion of a portion of the coal charged yields the heat required, and from which the gases escape direct into the atmosphere, in recent years many beehive ovens have been erected in which external heating is employed, the fuel used being the coke-oven gases, which are not allowed to escape, as in the older furnaces, but are caught and used for this and other purposes.

The Recovery of By-Products.—G. Lunge * comments strongly on the disinclination to adopt coke-ovens adapted for the recovery of by-products in England and America. The development from the French oven of Carvès to the Otto-Hoffmann and the Semet Solvay ovens is traced, and the beehive and modified beehive adapted for by-product recovery are condemned. In Germany the Otto-Hoffmann ovens are finding most favour, and the most recent modifications are described. Benzol recovery has been the most important step in recent years. Two processes have been used: cooling the gases under pressure, or absorbing in heavy oils from which benzol is recovered by distillation. The enormous production of benzol by these means rapidly decreased its price, and led to its use for enriching illuminating gas. Coke-oven tars are similar to ordinary gas tars, but beehive tars are of an oily nature and are practically useless. The benzol recovery processes have been kept very secret, but the author has with difficulty obtained two samples derived by the two processes mentioned above, and of these he gives full analyses. They contain 85.10 and 67.03 per cent. by weight of benzene, and 11.63 and 15.61 per cent. of toluene respectively for absorption and compression products. The balance is made up of compounds. Blannett has given the benzol production as high as 1 per cent. of the coal, but the author gives it as 0.3 to 0.4 per cent. of crude benzol, containing 93½ to 90 per cent. The recovery of ammonium sulphate and caustic ammonia is also described, and the author illustrates in some detail the appliances in use. Statistics are appended to show productions and prices.

* *The Mineral Industry*, vol. v. pp. 179-198.

C. Heinzerling* describes a combined compression and absorption process devised by himself for the recovery of benzol from coke-oven gases.

G. B. Walker and L. T. O'Shea† deal with recent progress in the recovery of by-products from coke-ovens. The chemistry of coking and the composition of the products, coke, tar, and ammonia, is first discussed, and then the evolution of the by-product oven is described. Short accounts are, for this purpose, given of the Carvès, Simon-Carvès, Semet-Solvay, Otto, Collin, and Brunck ovens. In using retort ovens it is very necessary that the process be worked continuously, to avoid the loss of heat that occurs when an oven is not recharged directly the previous charge is finished.

H. Bonser‡ deals with the recovery of cyanogen and other residual products from the waste gases of coke-ovens. The Holmes scrubber is referred to, and the process for recovery of cyanogen consists in washing the gases after they are freed from ammonia by alkaline liquor containing carbonate of iron in suspension. Sodium ferro-cyanide is formed, and the liquor is evaporated down to produce cake, which is sold. On an average 5 lbs. of this salt is produced per ton of coal.

W. G. Irwin§ gives some excellent photographic reproductions of by-product ovens, chiefly Semet-Solvay and beehive ovens, as used at various works in Europe and America. Mention is also made of the Otto-Hoffmann and other types of ovens, and the collection of by-products and their use are described.

S. J. Fowler|| discusses the by-product ovens from the standpoint of a gas manufacturer, and shows that the retort oven is to be preferred unless there is a special demand for the harder coke.

The utilisation of benzol for the purpose of increasing the illuminating power of coal-gas has been studied at length by the Verein zur Beförderung des Gewerbflusses.¶ It is pointed out that in the United Kingdom the quantity of coal subjected to dry distillation in the gas-works is relatively enormous. Thus, in 1895, 11,937,000 tons were so treated as compared with 1,516,000 tons** in Germany. Per head of

* *The Mineral Industry*, vol. v. pp. 199-201.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 302-327, with two plates.

‡ *Ibid.*, pp. 335-340, with illustration.

§ *Cassier's Magazine*, vol. xii. pp. 581-592.

|| Paper read before the New England Association of Gas Engineers, through the *American Manufacturer*, vol. lx. p. 410.

¶ *Stahl und Eisen*, vol. xvii. pp. 531-534.

** 11,937 millions and 1516 millions in the original.

population London makes yearly 5580 cubic feet of gas, whilst in Berlin this quantity is only 2825 cubic feet. In previous years the quantities were smaller, but still they were much larger than the German totals. In making such large quantities of gas large quantities of tar are also made, the utilisation of which by distillation was first introduced in the United Kingdom, and has led for a long time past to the importation of considerable quantities of benzol into Germany. The yield of benzol from the tar is not a high one, amounting to but about $1\frac{1}{2}$ per cent., or considerably less even if the retorts are run very hot. In distilling coal about 92 per cent. of the total available quantity of benzol passes into the gas, only 8 per cent. being collected in the tar. Another source of benzol besides those mentioned lies in the distillation of petroleum residues, especially those from Baku. At the end of the eighties utilisation of arrangements in connection with coke-ovens for the collection and subsequent treatment of the by-products led to large quantities of benzol being placed on the market from this source, and this has since developed to such an extent that in 1896 no less than from 4500 to 5000 tons were produced in Germany from coke-ovens alone, fully three times the quantity produced during the same period in Germany from gasworks. The fall in prices resulting on the increased production led to no new works for the collection of benzol being erected. The demand, however, has been greater than expected, and the price has risen considerably. This, again, has led to a number of new plants being erected. The enormous changes in price to which the benzol is subject prevents this from being the direct object for which a works would be erected, and it must always be merely a by-product to some other industry. These constant changes in price have led to naphthalene, to some extent, being used with advantage as a substitute for benzol. In Germany some 14,000,000 tons of coal are coked annually, and about 40 per cent. of this is distilled in closed chambers. Assuming that the yield should be about 0.65 per cent. of benzol of 90 per cent. strength, this German yield would amount to 30,000 tons of benzol a year, or as much as 80,000 tons if all the German coke-ovens were supplied with condensation plant. The actual consumption in German aniline works and gasworks in 1896 was, however, only some 20,000 tons. The results of a series of experiments are given to show the advantage to be derived from the use of benzol as an addition to other illuminants in increasing their illuminating power.

Coke-Firing.—A treatise has been published by Oscar Simmersbach * on coke-firing as a means of smoke abatement. He shows that in Germany 10,000,000 tons of coal pass into the atmosphere unconsumed. Attempts have been made with more or less success to lessen this waste by the employment of apparatus for firing with powdered coal. The difficulty of preparing and storing the coal-dust, and the great cost of maintenance, militate, however, against the general adoption of such methods of smoke abatement. The one method of effecting this satisfactorily is thought by the author to consist in heating with coke. He shows that coke offers the following advantages in comparison with coal:—(1) Smokeless combustion; (2) less loss of heat, and consequently economy in fuel; (3) less deleterious action on iron grates; (4) absence of clinker; (5) absence of spontaneous combustion; (6) no deterioration due to weathering; (7) less skilled stoking required; (8) absence of sparks; (9) greater evaporating power; (10) uniform evaporation; and (11) economical and pecuniary saving. Incidentally the author gives some interesting statistical details regarding coke. The first statistics of coke consumption on the Prussian railways date from the year 1844, when 24,940 tons were used. Ten years later the consumption rose to 182,000 tons, and reached its maximum in 1858 with 256,000 tons. In the following year coal was mixed with coke for locomotive use, and the Prussian railways used 20,000 tons less. Since 1860 coke-firing has been replaced by coal-firing. The chief reason for this was the poor quality of the coke then made. Now-a-days, however, there is no difficulty in obtaining ample supplies of good coke. In the Dortmund district, for example, in 1850 only 73,112 tons were produced; the out-turn rose in 1860 to 197,558 tons; in 1870 to 341,033 tons; in 1880 to 2,280,000 tons; in 1890 to 4,187,780 tons; and in 1895 to 5,562,503 tons. The coke production of the various German coalfields was as follows:—

	Tons.
Westphalia	5,398,612
Upper Silesia	1,121,587
Saar	695,045
Lower Silesia	415,963
Aix-la-Chapelle	207,098
Saxony	78,600
Obernkirchen	24,486

The growth of the coke production of the German Empire has been well marked of recent years, as is shown by the following statistics:—

* *Die Koksfeuerung*: Gelsenkirchen, 1897.

Year.	Production. Tons.
1890	6,411,520
1891	6,712,090
1892	6,843,330
1893	7,099,218
1894	7,941,391

V.—LIQUID FUEL.

Progress in the Petroleum Industry.—R. Kissling,* discussing various points with reference to the petroleum industry, deals with the dangers connected with the use of this material for illuminating purposes, together with standard methods of testing. This latter point, he observes, is still in the embryonic stage. Treating next of the production and trade in this article, he points out that Freystedt has thoroughly studied the Oelheim district, and that a further opening up of this district may result. In Austria there has been an enormous increase in the past two years in the output of raw petroleum, rich finds of oil having been made in Galicia, especially at Schodnica. The result has been that the home requirements of Austria-Hungary have been entirely met from these home supplies. In Russia, too, new and considerable finds of oil have been made, and among these is to be mentioned that of Grosny, in the Northern Caucasus. It is stated that the Vladikavkas Railway is erecting a refinery to treat the Grosny oil, in the first instance for the purpose of preparing fuel for the line. The Derbent oil district has been described by Charitschkoff. In this, as in some other districts, the percentage of illuminating oil increases with the increasing depth from which the oil is derived. The progress of the oil industry of Burma is also referred to. The improvements in distillation and refining are next passed in review, a number of these being briefly considered. Experiments made by Ostrejko have shown that petroleum will dissolve carbon dioxide and oxygen in the dark, and in sunlight nitrogen, nitrogen monoxide, and hydrogen are also dissolved. He points out, therefore, that to draw conclusions as to the origin of a petroleum from the gases it evolves is quite impossible. In Russia new tests have been officially instituted, which deal with the flashing point, specific gravity, and purity of the products. Various proposed analytical methods are also mentioned, and the use of the oil

* *Chemiker Zeitung*, vol. xxi. pp. 508-510.

is also considered, with numerous suggested improvements connected with its better utilisation.

The *Board of Trade Journal** gives particulars derived from various official sources of the state of the petroleum industry in Russia, the Dutch East Indies, Roumania, and the United States.

It is stated† that oil has been found on the surface of some puddles in the Doussard Forest, Haute Savoie, France, and that the geological structure of the district resembles that of the Roumanian oil-fields.

Oil‡ has also been found in a well sunk in a brickfield near Maestricht, Holland.

The Composition of Petroleum.—S. Young and G. L. Thomas§ have succeeded in separating normal pentane from isopentane in American petroleum. Details of the fractionation are given, and the properties of the normal pentane thus obtained are given by the former author.

K. W. Charitschkoff|| observes that that fraction of the Grosno petroleum which boils at temperatures not exceeding 150° somewhat resembles in appearance Ohio oil, but it has a disagreeable smell, which purification by the chemicals ordinarily used does not remove. In the belief that this smell had its origin in the presence of sulphur compounds, the author endeavoured to ascertain what these were. The investigation which he made for this purpose is described. This led to the discovery of a number of new mercury compounds. The presence of sulphur compounds of varying composition, as anticipated by the author, was proved by his experiments. He deals with some interesting points which more particularly relate to organic chemistry.

Petroleum in Galicia.—Professor R. Zuber has published a map of the oil-fields of Galicia, with a memoir, written in German, on the economic geology of the district. The region is one of great geological interest and complexity, whilst the language offers a greater barrier both to travel and to a study of the literature than is the case in many more remote regions. Professor Zuber's memoir is, therefore, all the more welcome.

* Vol. xxiii. pp. 267-272.

† *Engineer*, vol. lxxxiii. p. 446.

‡ *Chemical Trade Journal*, through the *Engineering and Mining Journal*, vol. lxiii. p. 512.

§ *Journal of the Chemical Society*, vol. lxxi. pp. 440-446.

|| *Trudy kak. otd. imp. russk. techn. obschtsch.*, vol. xii. p. 272; *Chemiker Zeitung*, vol. xxi.; *Repertorium*, p. 203.

E. Tietze * discusses the geology of Galicia with special reference to the views propounded by H. Walter.

The oil production in Galicia for 1896 is given † as 339,765 metric tons, or about 2,300,000 barrels.

Petroleum in Italy.—At a meeting of the Milan Institute of Science and Letters, Professor T. Taramelli reported on a borehole recently put down at Salsomaggiore, which yielded an abundant supply of petroleum. The oil is mixed with salt water, and is accompanied by natural gas. Unfortunately, the stratigraphical conditions of the district preclude the possibility of further underground oil-fields being discovered. ‡

Bitumen in Albania.—An interesting exhibit at the Brussels Exhibition was that of the Selenitza mines of Albania. It consisted of crude and manufactured bitumen of various kinds. The deposit is of Pliocene age, the bitumen occurring in irregular masses in sandstone and conglomerate. On analysis it yields 43 per cent. of petroleum, 43 per cent. of fixed carbon, and 14 per cent. of ash. The deposit is worked on a large scale by a French company. §

Petroleum in Roumania.—The oil production of Roumania for 1895 is given as 455,000 barrels, the larger proportion of which is worked up for local consumption. The crude oil contains 10 per cent. of benzol, 61.28 per cent. of first quality illuminating oil, and 20.6 of second quality, 2.2 of paraffin, and 5.89 of residuum. ||

Petroleum in the Caucasus.—J. A. Akunjanz ¶ observes that a petroleum found in the neighbourhood of the town of Kuba is quite different in appearance from other kinds found in the Caucasus. By reflected light its colour is light brown, but by transmitted light it forms a transparent blood-red liquid. Its smell is somewhat pleasant. At 15° C. it has the specific gravity 0.81465. Its flashing point is 25° C. Its outflow velocity, as determined by the Lamanskij-Nobel

* *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlv. pp. 386-410.

† *Naphtha*, through the *American Manufacturer*, vol. lx. p. 914.

‡ *Rassegna Mineraria*, vol. vii. pp. 17-19.

§ *Echo des Mines*, vol. xxiii. pp. 2557-2559.

|| *American Manufacturer*, vol. lx. p. 481.

¶ *Trudy bak. otd. imp. russk. techn. obschtsch.*, vol. xii. p. 157; *Chemiker Zeitung*, vol. xxi.; *Repertorium*, p. 191.

apparatus, is 1' 17" at 50°. On fractional distillation the author obtained the following products:—

Boiling Point.	Yield.	Specific Gravity.	Flashing Point.
Deg. C.	Per Cent.		Deg. C.
Up to 150	4.28	...	...
150 to 270	49.26	0.7797	23
270 to 300	13.63	0.8197	102

It was thus possible to obtain a total distillate amounting to 62.89 per cent., with a specific gravity of 0.79116. The residue consisted of a reddish-brown mass, which, at 15° C., thickened to a semi-fluid paste with an outflow velocity of 1' 48", and containing 3.61 per cent. of paraffin. The hydrocarbons in this residue appear, therefore, to harden at low temperature, without, however, being identical with paraffin. The author observes that the general behaviour of this oil is such that it would almost seem as if it had been subjected to a natural process of distillation. On treatment with concentrated sulphuric acid, only 7.03 per cent. of the oil was taken up, 92.97 per cent. consisting of saturated hydrocarbons. Neither aromatic compounds nor naphthenes could be found in the unsaturated hydrocarbons separated by the sulphuric acid. The refined petroleum obtained from this oil has a low illuminating power.

E. Juschkin* describes the Chidrisinde naphtha deposit near Darbent, Caucasia. He gives the results of boring operations, and discusses the results obtained. He considers the deposits of little importance.

It is pointed out,† however, that the opposite view is held by Lissenko and Dsybenko, who consider that the boreholes put down have not yet reached the true naphtha-bearing beds. Sorokin, too, thinks that this deposit will prove of a payable character.

A. Konchin‡ gives a few geological details and sections of the Baku and adjoining oil-fields in Russia.

Petroleum in Canada.—The Annual Report of the Geological Survey of Canada contains an account of the boring for petroleum in the tar sands of Athabasca Landing, Alberta, from which it appears that they can be reached at a depth of 1800 feet. These petroleum deposits extend for 150 miles along the Athabasca Valley.

* *Report of the Baku Section of the Imperial Russian Technical Society*, 1897, p. 231.

† *Chemiker Zeitung*, vol. xxi.; *Repertorium*, p. 191.

‡ *Guide des Excursions du VII. Congrès Géologique International*, No. xxiv.

Dr. Dawson, of the Survey, proposes to sink experimental wells at different points.

The petroleum field of Lambton County, in Western Ontario, continues to be the only considerable source of supply in Canada, and the average production of the wells is eight to ten barrels monthly. The wells have a long life, and new wells are constantly being put down.*

Petroleum in Upper Burma.—Dr. Noetling's report on the Yenangyoung fields will be published shortly.† It appears that this field is showing signs of exhaustion. The dug wells in the district are now sunk with the aid of the diving-dress, without the weights used under water. Six of these dresses are in use, and the men can stay down any length of time, instead of only a few seconds as was previously the case, on account of the noxious vapours. The further survey of the Yenangyat oil-field has shown two more exposures of Pliocene beds along the same anticlinal, which may be regarded as future oil-fields. One lies south of the Irawadi, to the south of Singu, in the Yenangyoung oil-fields survey, and the other is north of Yenangyat. The latter is larger, and beds of Miocene age crop out along the axis of the anticlinal, the first oil-sand of the Yenangyat borings being exposed at the surface. At one place the hill is reported to have been on fire.‡

Petroleum in Japan.—There is a growing demand in Japan for kerosene oil, and new sources of supply are being developed. It is not only being used for illuminating purposes, but for motive power. The oil districts of Japan extend from Hokkaido to Akita on the north, traverse the provinces of Echigo and Shinano and reach the Totomi province. In the Tosan district over fifty well-boring rigs are being set up, whilst about thirty others are about to be erected. Now, with improved boring machinery, depths from 800 feet to 2000 feet are reached. The process of refining has also been greatly improved, so that Japanese oil is now practically the same in quality as foreign petroleum.§

The Oil-Fields of Java and Sumatra.—A Dutch company has produced a considerable quantity of oil from the Java and Sumatra

* *The Canadian Mining Iron and Steel Manual*, 1897, pp. 302-319.

† *Records of the Geological Survey of India*, vol. xxx. p. 7.

‡ *Ibid.*, p. 111.

§ *Industries and Iron*, vol. xxiii. p. 337.

oil-fields, and is extending its operations.* The Sourabaya field consists of the Lidah pool with about twenty-five flowing wells, and the Koetei pool with fifteen flowing and pumping wells. In the recently discovered Matatoe pool there are two wells producing 400 and 1000 barrels daily. The Rembang field comprises the Panolan pool with fifteen flowing wells, and other pools belonging to other companies. There are two refineries at work, one in each of these fields, and a third is to be started. Another company† has sunk boreholes in the Palembang field with successful results. Much gas comes off with the oil.

K. Redlich‡ draws attention to an official report by M. Verbeek and R. Fennema on the geology of Java. Petroleum has been found at various places, and a considerable number of wells have been recently put down in Sourabaya. These have found oil of good quality. The daily out-turn of refined petroleum is now about 96,000 gallons. The oil is found in a Miocene formation. *Nodosaria*, *Dentalina*, *Globigerina*, and *Rotalina* have been found in large quantities, but fossil remains of other kinds are absent.

Petroleum in the United States.—G. E. Walsh§ gives an illustrated historical account of the oil-fields of the United States. The first oil-well was drilled by Colonel Drake in 1859, near Titusville, Pennsylvania, the height of the derrick being 34 feet, as compared with a modern 80-foot derrick. A portrait of Colonel Drake is given. Other illustrations comprise a nest of derricks in the centre of the oil-town Cygnet, in Ohio, pumping oil from a well, a view of an oil-tank farm, pumping oil from a well into a small tank to be transferred to a larger tank, a 35,000-barrel tank in course of construction, oil-tanks struck by lightning, interior of the pumping station near Cygnet, the oil-pumping station near Cygnet, the largest in the world, and shooting an oil-well.

Petroleum in Pennsylvania.—An oil company in Pennsylvania is erecting an electrical power plant to supply power for drilling new wells and for pumping all its wells in the vicinity. If the plan

* *Chemische und Technische Zeitung*, through the *American Manufacturer*, vol. lx. p. 589.

† *Ibid.*, through *Ibid.*, vol. lx. p. 914.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 419.

§ *Cassier's Magazine*, vol. xii. pp. 663-675.

proves successful, it will, no doubt, lead to a very extensive use of electric power in the oil regions.

Compressed air has been successfully used in the Bradford district for driving the pumps used in the oil-wells.*

Petroleum in Texas.—Petroleum was discovered at Corsicana, Texas, early in 1897, at a depth of 1040 feet. According to the *Pittsburg Times*, the oil obtained is better than Ohio oil, but not so good as that found in Pennsylvania. An analysis showed 90 per cent. of volatile matter and 10 per cent. of residue. The oil-field covers an area of 150 acres. It costs £300 to put down a well, and the oil sells at Corsicana for three shillings a barrel.

The Petroleum Fields of Wyoming.—According to W. C. Knight,† oil was discovered in Wyoming about a quarter of a century prior to the great Pennsylvania excitement, but the oil industry of the State was only intermittent and small until 1894, when it was placed on a paying basis by wells at Caspar, in the Salt Creek basin. The oil-fields are numerous and extensive, eighteen being known. The largest extends for twenty-five miles along the Rattlesnake range in Natrona county, and another of similar size occurs at the foot of the Wind River range. Many others are 3 to 10 miles long; none of them are wide, as the strata dip rapidly. The specific gravity of the oils range from 0.865 to 0.995, mostly being lubricating oils. The lowest oil horizon is the Upper Carboniferous, or possibly Permian, and the upper limit is the Wasatch Eocene. The total thickness between these formations is 10,000 to 15,000 feet. The author then describes the known fields in some detail.

Asphalt.—G. W. Tillson ‡ deals with the production of asphalt and its use for paving purposes. Various opinions are held as to its composition, and these are briefly mentioned. Then a brief description is given of the Trinidad pitch lake, and of the deposits in California and other parts of the United States.

The production of asphalt and bituminous sandstone decreased in the United States in 1896, but that of asphaltic limestone increased. In California a works is being erected for the treatment of asphalt,

* *American Manufacturer*, vol. ix. p. 914.

† *The Mineral Industry*, vol. v. pp. 442-450.

‡ *Transactions of the American Society of Civil Engineers*, vol. xxiii. pp. 179-199.

which includes dissolving out the crude material in naphtha, carrying the solution through a pipe line 30 miles in length, and pumping back the solvent.*

VI.—NATURAL GAS.

Natural Gas in the United States.—A. Mallet † gives some interesting details of the importance of the natural gas industry in the United States. The total value of the natural gas utilised in that country in 1895 was 67,700,000 francs. The number of oil-wells at work amounted to 3826, and the length of the pipes serving for the distribution of the gas was not less than 18,362 kilometres.

The report of the State Geologist of Indiana predicts the failure of the natural gas supply in the near future. The territory that now produces natural gas covers 2500 square miles, and no new discoveries are likely to be made. A decrease in the pressure was first noticeable in 1895, and it is still diminishing.

The natural gas-well on Binning's farm, near Baldwinsville, New York, is said ‡ to be the most prolific yet found in New York. It is 2520 feet deep. The force of the gas will lift a weight of 300 lbs. placed over the tube opening. The well is now being piped to save the gas, as the flow is estimated at over 5,000,000 cubic feet in twenty-four hours.

During the year 1896 the pressure of gas in all the United States fields has continued to fall, and no new fields have been opened up. Some companies have added gas compressors to their plant in order to make the gas-pipe lines carry the required amount of gas, which they could not do at a lower pressure. In some instances the pressure in pumped wells is below that of the atmosphere. The values of the natural gas produced in 1895 and 1896 are nearly identical, being approximately £2,600,000 in both years. Other statistical details are also given. §

* *The Mineral Industry*, vol. v. pp. 45-48.

† *Bulletin de la Société des Ingénieurs Civils*, vol. I. pp. 795-798.

‡ *Engineering News*, vol. xxxviii. p. 64.

§ Eighteenth Annual Report of the United States Geological Survey.

VII.—ARTIFICIAL GAS.

A Comparison of Fuel-Gas Processes.—F. L. Slocum * divides the methods of producing fuel-gas into three classes: (1.) Coal-gas production by distillation, including by-products ovens; (2.) Bituminous coal water-gas producers, or intermittent machines using bituminous coal, blowing or heating with air, and then decomposing steam; (3.) Producers, or continuous gas machines, of the Mond and Siemens type. These methods are classified according to the heating value of a cubic foot of the gas which they respectively produce. Perhaps the greatest detriment to the more rapid development of successful fuel-gas processes has been the so far unattainable ideal in heating value per unit of the natural product—*i.e.* 980 British thermal units per cubic foot. In the first class gas giving 600 heat units can readily be made. The best developed machines of the bituminous coal water-gas producers are the Hastings and the Loomis. The regular water-gas machines are not considered, as they use only expensive fuel, and produce a lower heating value gas. The results of some tests with the Hastings producer are given. Analyses of the gas made were as follows:—

	First.	Second.
	Per Cent.	Per Cent.
Carbonic anhydride	7.90	8.10
Illuminants	1.40	1.10
Oxygen	0.10	0.30
Carbonic oxide	28.50	28.10
Hydrogen	48.40	49.65
Marsh gas	8.20	9.82
Nitrogen	5.25	3.95

The calorimeter test gave 390 British thermal units per cubic foot, which shows that by a more careful exclusion of nitrogen and a proper reduction of the carbon dioxide there will be no difficulty in making and maintaining a 400 unit gas. With proper appliances for utilising the producer-gas formed during blowing, and the saving of the waste heat in the gas made, the net actual efficiency should be raised to at least 70 per cent. of the fuel charged, while any class of fuel can be

* *Journal of the Society of Chemical Industry*, vol. xvi. pp. 420-424.

used. The net results per ton of coal would be approximately : 8 lbs. of sulphate of ammonia, and 52,000 cubic feet of 400 British thermal unit gas. A few particulars are then given of the Siemens and Mond producer-gas, and some typical analyses of the various gases are given, and it is stated that the quantity of air necessary to burn completely one cubic foot of each of these gases is as follows: Natural gas, 9·80 cubic feet; coal-gas, 5·65 cubic feet; bituminous water-gas, 2·97 cubic feet; Mond gas, 1·25 cubic foot.

F. H. Shelton* describes the commercial failure of attempts to supply fuel-gas in the United States, and gives a history of the several trials that have been made. In the discussion which ensued, his conclusions were supported by one of the makers, D. M'Donald, who thinks that coal or illuminating gas must be used.

The Kitson Gas-Producer.—J. E. Fry† describes at length the Kitson gas-producer, and some tests made with it at Philadelphia. In this producer there is a uniform and continuous agitation of the fuel bed, removal of ash, and feed of coal. The internal diameters are 7 feet above the hearth, tapering to 4 feet at a height of 12 feet. The hearth is rotary, being carried by ball-bearings, and revolved first in one direction and then in the other through a complete revolution by worm-gearing. Its top surface is inclined, one edge being two feet higher than the other, so that it continuously stirs up the bed. The ash-pit is water-sealed, and air and steam are supplied through the hollow shaft of the grate. When anthracite is used, the hearth is given one revolution in forty minutes, and with bituminous coal in twenty to thirty minutes. Less than two horse-power is used for driving the mechanism and supplying blast. Anthracite culm was used in the tests. On assay this showed :—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Total.
6·45	8·83	66·99	17·73	100·00

The gas produced had the following composition by volume :—

CO ₂ .	CO.	O.	H.	CH ₄ .	N.	Total.
3·5	30·0	0·5	12·0	0·7	53·3	100·0

and its calorific value in British thermal units was 144 per cubic foot. A thousand cubic feet of gas is yielded by 13·78 lbs. of dry culm,

* Paper read before the Western Gas Association, through the *Engineering News*, vol. xxxviii. pp. 108-111.

† *Iron Age*, vol. lx. No. 14, pp. 12-16.

and the author gives thermal calculations regarding this production. His last table summarising the results is as follows:—

	Thermal British Units.	Per Cent.
Total thermal value of 13·78 lbs. of dry culm	173,476	100·00
Heat losses by—		
Steam	454	0·250
Gas	12,830	7·395
Moisture of culm	1,080	0·623
Latent heat of gasification	14,822	8·544
Ash refuse	4,010	2·312
Radiation, by difference	3,682	2·123
Total loss in gasification	36,878	21·247
Cold gas efficiency		78·753

If the gas were used hot, 86·561 per cent. of the heat would be available.

The Dellwick Gas Producer.—Dicke * describes the Dellwick producer as used with coke, coal, and lignite to produce water-gas. When coal is used, it is coked in the upper part. The lignite apparatus has an inclined grate.

A Modern Gas-Power Plant.—Horace Allen † gives the results of some tests of a gas generator plant of 300 horse-power capacity, and working on the Thwaite patent continuous cycle. The apparatus consists of two cylindrical vessels side by side. The fuel is fed into the hopper at the top, and air is supplied by a fan driven from the main engine. The gas, as it leaves the bottom of the second generator, has a high temperature, and is made to heat the incoming air by means of a recuperator apparatus, thus restoring a considerable amount of heat to the generators. From the recuperators the gas passes through a purifier to the pressure governor-holder, which automatically governs the supply of gas to balance the demand, and from which the gas-engine receives its supply. Analyses of the gas show the following average percentage composition by volume:—

Carbonic acid	4·0	2·5	6·6	5·1	3·8	2·8
Carbonic oxide	27·4	28·3	22·6	23·2	26·1	28·2
Hydrogen	6·9	6·6	8·7	7·0	6·6	4·1
Marsh gas	2·0	2·4	0·9	1·4	1·8	1·8
Nitrogen	59·7	60·2	61·2	63·3	61·7	63·1
	100·0	100·0	100·0	100·0	100·0	100·0

* Paper read before the Dutch Gas Engineers, at Groningen, through the *American Manufacturer*, vol. lx. p. 410.

† *Engineer*, vol. lxxxiv. p. 420.

The gas was made from coke only, or from coal and coke mixed. The thermal value ranged from 111 to 138 British thermal units per cubic foot. Eighty-one cubic feet of gas, in one experiment, were used per indicated horse-power hour, representing 1 lb. of coke. The hourly production of the plant is 17,400 cubic feet, and the indicated horse-power ranged from 113 to 139 indicated horse-power.

Producer Gas from Anthracite Waste.—J. G. Sanderson * gives the following analysis of gas made by his producer from the culm or waste anthracite in Pennsylvania:—

CO.	H.	O.	CH ₄	CO ₂	N.
28.80	19.85	0.40	0.66	3.80	46.49

VIII.—COAL-MINING.

Sinking Shafts.—F. R. Simpson † gives some notes on the sinking of two shafts at Claravale Colliery, near Wylam-upon-Tyne. These shafts are 99 feet apart, each 14 feet in diameter, and are sunk to the Brockwell seam, at a depth of 395 feet. Owing to the unexpected quantity of water, the sinking took three years, as much as 2000 gallons per minute having to be dealt with for some time, in place of 500 gallons, as was expected. The author chiefly devotes his account to the pumping appliances, which were added to from time to time as the water increased, until at one time a 24-inch set was working in one shaft and an 18-inch set in the other. Tubbing was put in to exclude one feeder of about 950 gallons per minute, and the water now dealt with amounts to about 1100 gallons per minute.

In some notes by G. Caldwell ‡ on the sinking at the Maypole House Colliery, Abram, an analysis is given of the water, which has been encountered in great quantity, as much as 120,000 gallons being raised hourly.

J. P. Kenrick § describes the sinking operations at Kingsbury Colliery, Warwickshire. The pits, 16 feet in diameter and 165 feet apart, are intended to work the rider seam at a depth of 624 feet, and the

* *Coal Trade Journal*, through the *American Manufacturer*, vol. lx. p. 771.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 193-199, with one plate.

‡ *Transactions of the Manchester Geological Society*, vol. xxv. pp. 238-246.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 269-276, with one plate.

seven-foot seam 210 feet below the former. Two feeders, each averaging 60,000 gallons per hour, were met with in a bed of soft grey sandstone, at depths of 135 and 192 feet. Evans pumps were slung in the shafts to cope with the water, which was ultimately tubbed out. Temporary lining used during sinking was composed of iron rings 3 inches by $\frac{7}{8}$ inch in section, backed with deals. A suspended stage was used during walling and tubbing. A section of the strata passed through is appended.

Illustrations have appeared * of M'Culloch's frame for use in sinking shafts. It consists of a number of stretcher bars adjustably but rigidly connected together and braced against the sides of the shafts. It is supported by ropes passing over a head gear to a winding drum. A loose rider runs on these supporting ropes, and acts as a guide for the kibble. By flooring over the frame it can be used as a walling scaffold.

At the Preussen Colliery, near Dortmund, an interesting experiment has been successfully made with the tubbing for a shaft sunk by the Kind-Chaudron method. The shaft, which was bored with a diameter of 14 feet 9 inches, reached the Coal Measures at a depth of 1760 feet. For lining the last 260 feet seventy-three cast iron rings were provided. They were 13 feet 6 inches in internal diameter and 4 feet high. During the sinking the level of the water was maintained at 750 feet below the surface. The tubbing was lowered by means of a special sinking apparatus fixed to the boring rods. The apparatus is formed of six arms, that can at will be made to clutch hold of the flanges of the tubbing rings. This is effected by turning the boring rods at the surface.

Th. Lichtenberger † describes the Honigmann system of boring or sinking shafts. The water in the shaft is mixed with clay, so as to bring its specific gravity up to 1.2, and the greater pressure thus obtained is designed to maintain the walls of the hole or shaft, especially in quicksand. It also assists in raising the material excavated through the boring rods into which air is led by a central pipe and allowed to bubble upwards so as to reduce the head. Two shafts have been sunk in the Oranje Nassau coalfield near Heerlen, in Holland, but as regards their success the discussion brought out a conflict of opinion.

* *Engineer*, vol. lxxxiv. pp. 428-429.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 155-159, 381, with one plate.

The Honigmann system of shaft-sinking has been successfully employed * at two shafts near Heerlen, in Holland. Difficulties which were experienced in the sinking of these shafts were, it is stated, in noways connected with the Honigmann method. The difficulties that had to be overcome were considerable, beds of quicksand being met with.

L. Verniory describes † the methods adopted for replacing wood tubbing by cast-iron tubbing at No. 3 winding-pit of the Wasmes Colliery. He gives an account of the enlargement of the diameter of the shaft and of the installation of the new tubbing.

Deepest Shaft in Saxony.—According to K. Menzel, ‡ the deepest shaft in Saxony is shaft No. II. of the Bockwa-Hohndorf Colliery in the Lugau-Oelsnitz district. This shaft has a depth of 2848 feet. The next deepest shafts are two belonging to the Hohndorf Colliery, with depths respectively of 2736 and 2691 feet. In the Zwickau coal district the deepest shaft is one near Zwickau having a depth of 2588 feet. In 1876 there existed in Saxony a shaft at Oelsnitz, now no longer in use, having a depth of 3047 feet.

Prevention of Ice in Shafts.—Various methods have been tried by Petit § for preventing the formation of ice in in-take shafts. The use of a fire for warming the shaft or for pre-heating the air entering it is only possible when there is no danger from gas, but it is always dangerous. Steam is also admitted into the shaft for this purpose, but this too has its disadvantages, for if too little steam is admitted to keep the air above the temperature of the freezing-point, it condenses and forms ice, and so increases the difficulty it was intended to prevent. If, on the other hand, too much steam is admitted, the thick mist that forms may become a nuisance and hinder the filling of the waggons. Duc || has employed at the Roche-la-Molière Colliery an arrangement of pipes heated by steam, and transmitting the heat of the steam to the air, only as much steam being admitted into the pipes as these will condense. Other methods are also described both for steam-heating and also for warming by

* *Glückauf*, vol. xxxiii. p. 292.

† *Revue Universelle des Mines*, vol. xxxviii. pp. 1-24.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 316.

§ *Comptes Rendus de la Société de l'Industrie Minérale*, 1897, pp. 3-11.

|| *Ibid.*, pp. 11-13.

means of heated air. In this latter process a kind of pipe hot-blast stove is used, and the air drawn through this by the fan and sent into the shaft.

Shaft Pillars.—Various rules are given for determining the size of shaft pillars. Merivale gives $S = \sqrt{\frac{D}{50}} \times 22$, where S is the length of the side in yards, and D the depth in fathoms. André allows 5 yards of side for every 25 yards of depth. Dron leaves solid coal round the boundary of the buildings equal to a third of the depth. Wardle assumes a minimum of 40 yards square for a depth of 60 fathoms, and adds 10 yards for every 20 fathoms of depth. Hughes leaves a yard in diameter for each yard in depth. Pamey adopts 40 yards square as a minimum up to 100 yards of depth, and adds 5 yards for every 20 yards in depth. None of these take into account the thickness of the seam, and it has been proposed to adopt the formula: radius of pillar equals three times the square root of the depth multiplied by the thickness.*

Winding Ropes.—Statistics have been issued † by the Dortmund Mining Bureau regarding the accidents with winding ropes that occurred at the collieries of the district last year. Out of 270 winding ropes discarded, five, or 1·85 per cent., broke suddenly while in use. Out of the 5405 ropes laid on one side during a period of twenty-five years from 1872 to 1896, 254, or 4·70 per cent., broke suddenly while in use. Out of the above numbers, breakages occurred in the case of 43 out of 736 flat cast-steel wire ropes, 19 out of 47 flat iron wire ropes, 7 out of 97 flat manilla fibre ropes, 80 out of 3536 round cast-steel wire ropes, and 105 out of 881 round iron wire ropes, while not one of the eight hemp ropes gave way. It is satisfactory to note that the number of fractures tends to decrease. In 1872 the percentage of wire ropes breaking was 19·30, whilst in 1896 it was reduced to 1·85.

K. Habemann ‡ deals statistically with the winding ropes of the Breslau mining district. He shows that during the fifteen years, 1882–1896, 40 out of the 1642 ropes that had been replaced broke suddenly while in use, as is shown in the following statement :—

* *Colliery Engineer and Metal Miner*, vol. xvii. pp. 538–539.

† *Glückauf*, vol. xxxiii. pp. 718–720.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 444–445.

Rope.	Total Number.	Number that Broke.	Per Cent.
Round, crucible cast steel	1379	19	1.38
Round, iron	117	11	9.40
Flat, crucible cast steel	146	10	6.85

In 1896, out of 145 replaced ropes, three had fractured. Two of these were round crucible cast-steel ropes, and one a flat crucible cast-steel rope. Details are given which show the work done by the different ropes before they were replaced. From this it is seen that the round ropes were much the more effective as compared with the flat ropes. The maximum work done by a round rope before it was replaced was 170,916,000 metre-tons, while for a flat rope the maximum was 21,929,000 metre-tons. The 145 ropes replaced were all of crucible cast steel, 134 being round and 11 flat.

A. Ehrenberg* gives the results of a series of tests of locked coil wire ropes, showing the advantages they possess as compared with ordinary winding ropes.

Ropes, it is pointed out by Ellingen,† are made of a large number of materials, but for works purposes only those of iron, steel, hemp, aloe, and cotton are of importance. Flax is not used for ropes. For colliery purposes wire ropes are usually employed, but aloe ropes are also occasionally used. The aloe fibre is somewhat stronger and more elastic than hemp, but less pliable than manilla. An important point in connection with the use of aloe ropes is their increase of tensile strength in damp shafts and in water. It is to this property, and to their great elasticity, that even now aloe ropes are almost solely employed in Belgium collieries, even for the greatest depths. The opinion that aloe or hemp ropes cannot be used for winding from great depths is erroneous, and so long as the ropes are not tarred they can be used for just as deep a shaft as steel ropes. It is the increase of weight due to tarring that gives steel an advantage over an aloe or hemp rope. The length of a free-hanging rope at which it will break by its own weight is about as follows:—

Material of Rope.	Yards.
Aloe	13,000
Crucible cast steel	13,550
Tarred hemp	6,500
Plough steel	21,700

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlv. pp. 149-165.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. pp. 775-777.

With a sixfold factor of safety, an aloë rope could thus be used for a shaft some 2200 yards in depth, a crucible steel rope for a 2300 yards shaft, a tarred hemp rope for a shaft 1100 yards deep, and one of plough-steel for a shaft 3600 yards in depth. In this calculation it is assumed that the ropes have only to support their own weight, and are of the same section throughout their whole length. To increase the strength of a rope, it is usual in manufacturing it to commence at the thin end, and to add one or more wires every five yards or so. In Germany round steel ropes are usually employed, having tensile strengths of 76 to 114 tons per square inch, the latter material being known as plough-steel. Locked wire ropes of the Felten and Guillaume type have in recent years been made in Germany, the spiral form of wire rope not having been previously in use there. The construction of the older form of rope is described, and other points are also referred to, ropes and their application being dealt with generally.

A cable for an aerial tramway to be used for transporting ore from the Nellie Mine to the town of Telluride, in Colorado, weighed 17,000 lbs., and was 13,200 feet long. It had to be transported whole up a narrow and dangerous pass. The task was finally accomplished by unwinding the cable and forming it into 128 coiled bundles of 130 lbs. each. These were fastened to the backs of mules, two to each animal, and the procession of sixty-four mules slowly made the dangerous ascent of 2500 feet. The same evening the cable was running, and it now handles ore that previously required 500 mules.*

Winding Engines.—Illustrations have been published † of a large pair of winding engines. The cylinders are of 41-inch diameter and 72-inch stroke with balanced slide valves. The principal dimensions are shown on the drawings, which include a plan and elevation.

According to Carl Habermann,‡ at the Ewald Mine, at Herten, there is a total of over 2300 horse-power of steam motors, including the large winding engine, air compressors, pumps, &c. The condenser here used is arranged in a separate building from the main engine-room, and consists of a system of brass tubes connected by return bends, forming a large box-coil standing in a room. These tubes are cooled by water dripping upon them from above, while a current of air enters from below and passes out above into a sheet iron stack, thus carrying

* *Colliery Guardian*, vol. lxxiv. p. 740.

† *Engineer*, vol. lxxxiv. p. 342, with folding plate.

‡ *Zeitschrift des Oesterr. Ingenieur und Architekten Vereines*, vol. xlix. pp. 45-48. 1897.—ii.

away the vapour from the room, and increasing the rapidity of the evaporation from the outside of the tubes. The water which drips from the tubes falls upon the series of inclined surfaces exposed to the incoming air, and is thus cooled, to be used again and again, being drawn from the collecting chamber below by a rotary pump, and delivered above to the condenser. The exhaust pipes from the various steam-engines all deliver into one large shell, which is connected to the condenser, and in this shell a vacuum is maintained of about 85 per cent. of the atmospheric pressure, or, with the barometer at 30 inches, about 12·5 lbs. The air-pump is worked by an independent engine, which also drives the circulating pump, and the speed is controlled by a regulator operated by the vacuum, thus keeping the latter quite uniform. This installation has been in operation for about a year, and has thus far shown an economy of about 17 per cent. in fuel, enabling two boilers to be dispensed with, besides furnishing pure feed-water and avoiding the formation of scale in the boilers. The particular apparatus described in the above case is that of Balcke & Co., of Bochum; but there are several other makers in Germany, and a list of eleven installations is given, aggregating 32,000 horse-power, of which 5500 horse-power is at Krupp's works at Essen, and 4000 at the Mannesmann Works at Komotau.

Underground Haulage.—W. J. Heppell* gives the cost of horse-haulage at the Cwmaman Colliery, South Wales. The distance that the coal had to be brought by horses varied from 169 to 900 yards, and the cost per ton-mile on coal and rubbish varied from 7·7d. to 1s. 7d. Full particulars are given in tabular form.

H. F. Bulman† gives a sketch of the branches along which tubs are taken from the faces to the collecting point in a pillar-and-stall working in Durham. The cost of pony-haulage is given.

J. Kersten‡ describes and illustrates the various devices used by G. Heckel for endless rope-haulage. Amongst these are driving pulleys with leather treads for the rope, channel iron instead of rails at curves, guide pulleys with loose rollers, several forms of cam and wedge rope-grips, &c.

J. Brown§ describes a haulage-clip in which a pair of eccentrically

* *Proceedings of the South Wales Institute of Engineers*, vol. xx. pp. 343-347.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 117-120.

‡ *Revue Universelle des Mines*, vol. xxxix. pp. 299-307.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. p. 147—
with illustration.

centred rollers are mounted on the arms of a fork to frictionally hold the rope.

In the Jorissen rope-haulage system the rope is free, and is borne by and rests on the waggons. At intervals of some 33 feet are knots in the rope, to which are attachments for hauling the waggons, and these, as well as the knots themselves, pass readily over vertical rollers, at the curves in the line. A spiral spring is in connection with the carrier attachments of the knots, lessening the concussion when the waggons are coupled on. An arrangement of horizontal rollers enables waggons to be connected or disconnected whenever required.*

G. J. Binns† gives some notes on the auxiliary haulage at Nether-seal Colliery. Compressed air engines are used, and a loose rope passing round a pulley at the working face is connected to the main rope, and used to haul the tub in-by when the incline is such as not to allow it to run in of itself. Other arrangements are also described, and plans of the workings are given.

R. Hirsch‡ deals with the transmission of power by compressed air, and gives an illustrated description of the pneumatic locomotives in use at Glen Lyon, Pennsylvania.§ Where it is possible to use a heater the economy is greatly increased.

J. J. Ormsbee|| gives a sketch of a "horse" used by colliers in descending inclines at the Whitwell Collieries, Marion County, Tennessee. It is made of a mule-shoe, with a board nailed on and a roller on its underside. In use the miner places it on the rail and uses his feet on the rail as a brake, steadying himself by placing his hand, guarded by a leather pad, on the haulage rope.

Electrical Transmission of Power.—A paper was read by F. J. Platt,¶ at a recent meeting of the Anthracite Coal Operators' Association, on electric mining machinery. The author brought forward a number of facts in regard to its successful use in the Pennsylvania anthracite mines, and showed its efficiency, its superiority over old methods, and its adaptability to various portions of the work-

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 355.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 256-268, with one plate.

‡ *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xiii. pp. 182-197.

§ *Journal of the Iron and Steel Institute*, 1895, No. II. p. 434.

|| *Colliery Engineer*, vol. xviii. p. 77.

¶ *Ibid.*, vol. xvii. pp. 483-485.

ings. The daily cost of working an electric haulage plant at Johnson's mines at Scranton was stated to be as follows:—

	s.	d.
Station engineer	7	0
Motor man	7	0
Helper	6	4
Repairs	3	0
Depreciation	7	7
Oil and waste	0	10
Total	31	9

The coal hauled per day amounted to 288 tons. The cost of haulage per ton was therefore 1½d. The cost by mule-power would be 3½d. per ton. In other instances of haulage cited by the author the cost per ton was as follows:—

Mine.	Electric Power.	Mule-Power.
	d.	d.
Peckville shaft	1·31	3·29
Peckville adit	0·85	1·17
Mount Pleasant mine	0·63	1·47

There are numerous electric pumps at work in the anthracite region, and they are all giving satisfaction. One of the largest is that at the Maltby shaft of the Lehigh Valley Coal Company. This has a capacity of 600 gallons against a head of 350 feet. It is driven by a 50 horse-power electric motor. The cost of working a pump installed by the author in an anthracite mine per day of twenty-four hours was as follows:—

	s.	d.
Repairs	1	10
Oil	0	5
Electrician	1	9
Total	4	0

Compared with working a steam-pump, the saving is at least 6s. Electric rotary drills are largely used in the region with very advantageous results. At the mine of the Dolph Coal Company the cost of driving headings with the electric drill is 15s. per yard, the cost of driving by hand being 24s. In all the figures given, no charge has been made for steam used by the generating plant.

H. St. J. Durnford and R. Holiday * describe the uses of electricity

* *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 232-241.

at Ackton Hall Colliery. Amongst other generating plant laid down are two 200 horse-power Parsons steam-turbines and dynamos. The current is used for lighting, driving the machinery in the workshops, pumping, haulage, and also for the coal-washing plant, with much success.

A large electric installation has been laid down at the Essen Coal Company's collieries, about 17 miles from Pittsburgh. Three dynamos, one being in reserve, generate the current for lighting, hauling, coal-cutting, and pumping. Electric locomotives of 80 horse-power each are used underground. A general description of the plant is given.*

Some illustrations of electrically-driven pumps, hoists, and coal-cutting machines have appeared, and the advantages of using alternating currents and three-phase motors are discussed.†

T. W. Sprague‡ generally reviews the use of electricity in mining. The generation of electricity direct from coal by the Jacques carbon battery is discussed, and the use of oil engines for driving electromotors is advocated. The use of storage batteries, electric power transmission, and the multiphase alternating current are briefly dealt with, and also coal-cutting machinery and underground haulage by electricity. At a colliery at Forest City, Pennsylvania, two electric locomotives are run tandem, all the controlling gear being placed on one machine, and a draw-bar pull of 5000 lbs. at 10 miles per hour is attained. Many collieries have now displaced mules altogether by electric haulage, and some figures are given to show the economy. The speed of electrically-driven undercutting machines has been increased, and a good many rotary coal-drills are now being driven by electromotors. The use of electric pumping machinery has also steadily increased.

W. G. Wilkins§ deals with the applications of electricity to mining. Amongst the points treated are the safety, efficiency, types of generators suitable for mining, and hints as to their selection, the engines to be used for driving the dynamos, and the general arrangements of the power-house, the conductors, coal-cutting machines, hauling, pumping and hoisting engines.

An account is published|| of the arrangements made for the trans-

* *American Manufacturer*, vol. lx. p. 408.

† *Colliery Engineer*, vol. xviii. pp. 53-55.

‡ *The Mineral Industry*, vol. v. pp. 733-742.

§ *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xiii. pp. 135-178, with illustrations.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv., Beilage, p. 50.

mission of power by the use of electricity at the Eleanora pit of the Witkowitz Mining and Ironworks Company. The current is to be used for pumping, hauling, ventilation, and general purposes, both below ground and at the surface.

Full details, accompanied by three sheets of illustrations, are published by O. Neuburger * of the new electric plant for the transmission of power at the Bleiberg mines. The water-power first employed at these mines was only comparatively recently replaced by steam, the available water-power at the mines varying enormously according to the season of the year. Steam-power proved costly, as wood had to be used for fuel. More water was subsequently met with in the mines than it would have paid to deal with by steam, and another source of power had consequently to be sought for. This has been found in the electric transmission of water-power, and this new plant is now described.

Preservation of Mine Timbers.—Wood tar, it is pointed out,† contains those materials which Nature herself uses for the preservation of wood, and its use is strongly advocated for this purpose. If the tar is rich in resinous matter, and fresh wood is tarred with it, it does more harm than good; but even a tar of this character may do good if applied to old wood which has been cracked by long exposure. The more oils the tar contains and the less resinous matter, the better the result.

J. Bateman ‡ describes the preparation of timber for underground use. Creosoting is to be preferred. The wood is placed in a wrought iron boiler, which is exhausted to a vacuum of 9 to 12 lbs. per square inch, and then creosote is pumped in to a pressure of 100 lbs. Fir and pine absorb 10 to 12 lbs. per cubic foot, oak and hard woods take up 6 lbs. The creosote should be rich in naphthalene.

At the Heinitz Colliery, near Saarbrücken, in places where the timber is destroyed more by decomposition than by pressure, it is painted with advantage with carbolineum. Whereas sound wood unpainted with this material, in part after even a single year, is entirely destroyed by decomposition, with the result that it has to be replaced, the timbers that have been treated with carbolineum are found after this period to show no traces of decomposition what-

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 569-576.

† *Glückauf*, vol. xxxiii. p. 639.

‡ *Journal of the British Society of Mining Students*, vol. xix.

ever. The timbers to be treated are first entirely barked, and then dried as far as may be possible. Subsequently they are painted over at grass once with carbolineum. In the mine itself all cut surfaces are painted over, and all timbers which show the least suspicion of going bad are also similarly painted. For timbers of 6 to 10 feet in length and up to 9 inches in diameter, the cost of treatment for a single piece of timber is only about three-halfpence. The saving to be effected by the use of carbolineum is undoubtedly very considerable, especially when it is considered that the cost for two supporting timbers and the one across at the top is only about ten shillings and fourpence in the case of the treated wood, as compared with ten shillings for that untreated.*

Iron Supports.—E. F. Melly † gives some notes on the use of steel girders and props in Griff Colliery, near Nuneaton. Dimensions and costs of girders and props are given, and it is shown that the loss is very small, and the results are very encouraging. Steel sprags 4 feet long, weighing 35 lbs. per yard, were experimented with, but they were liable to burst out unless lids were used, and their use was not pursued. Corrugated sheeting has been successfully used in the 7-foot seam to support the roof. For this purpose black corrugated arched sheets of No. 15 gauge, $5\frac{1}{2}$ feet wide by $2\frac{3}{4}$ feet long, with a spring in the arch of 15 inches, were used. Each sheet has seven corrugations, and the weight is 58 lbs. per lineal yard, and the cost is 4s. 4d. per lineal yard. These arched sheets are supported on the sides, a few bricks being used if necessary, and they have stood well for one and a half to two years.

Coal-Drills.—F. W. Fowler ‡ describes a drill for chambering the end of a borehole. The drill is of the twist type with a wing-cutter, which opens out when inserted in the hole.

An illustration has appeared § of a rotary drill driven by an electro-motor or a rotary pneumatic motor. The motor is of the multipolar

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlv. p. 213.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 277-282, with illustrations.

‡ Paper read before the Ohio Institute of Mining Engineers, through the *American Manufacturer*, vol. lx. p. 517.

§ *Engineering and Mining Journal*, vol. lxiv. p. 221; *Colliery Engineer*, vol. xviii. p. 80.

type, and with the gearing is completely cased in. The total weight of the stand, drill, and motor is about 150 lbs.

O. Derclaye * describes and illustrates the Liesens rotating hand-drill. The machine is simple in construction, and the operator soon becomes accustomed to its use under varying conditions. The method of using the machine is described.

At the Richter pit of the Laura-Hütte Colliery, in the Kattowitz district, a Siemens-and-Halske rock-drill is in use. It requires one horse-power, makes 420 blows in the minute, and can bore a hole in hard sandstone 4 inches deep in one minute. It weighs about 1 cwt., and the support to which it is attached rather more than as much again. Two men are required to work it.†

Driving an Adit.—The Bouches du Rhône Coal Mining Company‡ are driving an adit 8·7 miles long, with a slope of 1 in 1000, through hard and compact limestone. Electric rotary drills have been introduced, and power is supplied by a dynamo driven by a Pelton wheel placed 1·86 mile from the entrance in the tunnel, where water at a pressure of 113 lbs. per square inch is obtainable. A fifty horse-power plant has been installed. The turbine, which has an automatic governor, runs at 600 revolutions and drives direct on to a three-phase current dynamo. The drills are of the Bornet rotary type, with water forced through the bit to clear its crown. Each is driven by a separate three horse-power motor, geared down by spur-gearing. Nine drills are used, mounted adjustably on three carriages.

Explosives and Blasting.—The French Commission on Explosives has studied the question of storing explosives both underground and on the surface. The Blanzv Colliery Company placed at the disposal of the Committee the means of conducting three experiments on a large scale, and these were carried out in December 1895. A full description of them has now appeared.§ One magazine was constructed in a quarry. It was made as a T-shaped gallery, and the explosive was stored in the head or transverse gallery so as to fill one-hundredth of the space. If exploded, this would give a pressure of

* *Revue Universelle des Mines*, vol. xxxvii. p. 68-74.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlv. p. 204.

‡ *Le Génie Civil*, vol. xxx. p. 165.

§ *Annales des Mines*, vol. xi. pp. 89-119, with illustrations.

0.63 ton per square inch in the closed space. To prevent the gases escaping into the workings in case of explosion, a tamping block was placed in the gallery leading to the magazine, so that it might be blown against a seating to close the passage. The block was built of cardboard and wood nailed together to form a cylinder nearly 5 feet long and 5 feet in diameter, and the seating was built in as an annular block of concrete. The magazine was 32 feet long, $6\frac{1}{2}$ feet high, and 8 feet wide approximately, and contained half-a-ton of No. 1 dynamite. After the explosion, it was found that the tamping-block was driven firmly against its seating, but not seriously injured, and it is concluded that this system might be safely used underground. Two other trials were made with magazines constructed as open galleries, and showed that such a form might be used.

Several French mine owners having asked permission to replace the dynamite magazines on the surface by magazines underground, the Minister of Public Works instructed the Fire-Damp Commission to consider the best way of carrying these wishes into effect. Their report has now been published by M. Ledoux.*

F. Ritter v. Rziha† gives a complete bibliography in the blasting process from the year 1613 to 1767, and he shows that during the whole of this period the subject was treated purely empirically. Dealing then with blasting as applied in particular to mining purposes, the author gives a further complete bibliography from the year 1788, when Lavoisier expounded the first theory connected with this subject, down to the present time. He deals with the chemistry, physics, and mechanics of blasting in detail, and also with the blasting materials themselves and the process generally, as well as its several applications.

Experiments have been made at Saxon collieries with the explosive coal-carbonite in the place of black powder. At the Von Burgk collieries 2.2 tons of this explosive were used in 1896. Compared with black powder the results were not on the whole satisfactory. The percentage of lump coal diminished by five when carbonite was used, and the cost of explosive per ton of coal mined, was also greater. Similar results were observed at the Hänichen collieries. The carbonite when exploded yields unpleasant fumes. These unsatisfactory results are thought to be, in part at least, due to the fact that the

* *Annales des Mines*, vol. xi. pp. 517-543.

† Paper read before the Austrian Ingenieur und Architekten Verein; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv., Beilage, p. 67.

miners, unaccustomed to the explosive, used charges which were too heavy. Thus in the Zwickau district the collieries have adopted either this explosive or westphalite in such cases where shot-firing is still practised. Lithotrite was formerly used at the Falck Colliery, but is now no longer employed there, having been found to be too expensive.*

J. Ashworth † describes the Government apparatus for testing explosives to be used in coal-mines.

A memorandum has been issued by the Home Office setting forth the tests which explosives must undergo before they are admitted to the permitted list.

W. J. Orsman ‡ shortly discusses detonators and detonation. The detonators in use are charged with a mixture of fulminate of mercury and potassium chlorate. The latter should not exceed 5 per cent. for firing nitrate of ammonia explosives, but a larger quantity is advisable for nitroglycerine compounds. The sizes and contents of detonators are as follows:—

Number	1	2	3	4	5	6	6½	7	8
Grammes	0.30	0.40	0.54	0.65	0.80	1.00	1.25	1.50	2.0

Detonators are made abroad owing to the duty in this country on alcohol used in preparing the fulminate.

Some particulars have appeared § of the cost of blasting and amount of round and small coal produced with powder and various explosives, and also of the cost of brushing with powder and the explosives permitted. Both in cost and results the powder is best.

Coal-Cutting Machinery.—H. Gutmann || has published a detailed description of the coal-cutter used at the Pope and Pearson Colliery, near Leeds. The description is illustrated by three drawings.

E. W. Parker ¶ has prepared a table showing the use made of coal-cutting machinery in the United States. Fifteen States with 115 mines use 1139 machines, and have produced by their use 12½ million tons in 1896, out of a total tonnage of 96 million tons, a percentage of 13.06 as compared with 3.27 five years previously.

* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1896, p. 128; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 322-323.

† *Colliery Guardian*, vol. lxxiv. p. 153.

‡ *Transactions of the Manchester Geological Society*, vol. xxv. pp. 257-266.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 244-250.

|| *Glückauf*, vol. xxxiii. pp. 524-526.

¶ *Iron Age*, vol. lx. No. 8, p. 12.

R. M. Haseltine * gives some particulars of coal-cutting by machinery in Ohio. About $3\frac{1}{2}$ million tons were in 1896 mined with machines, as compared with $9\frac{1}{2}$ million tons by hand-labour, but the latter showed a decrease of over a million tons. The average machine production in wide work is 37·4 tons daily, as compared with 3·67 tons by hand-mining. In narrow work the machines produce 5·04 tons daily per man. Particulars of the wages paid and other statistics are given.

J. Hanford † discusses the merits of coal-cutting machines in view of the price paid for undercutting by hand, and points out how circumstances control the choice of type of machine and its driving power.

W. G. Wilkins ‡ gives an estimate of the cost of an electric mining plant to produce 800 tons daily of $1\frac{1}{2}$ -inch coal in the Pittsburgh district. Eight chain machines, undercutting 5 feet over 100 feet daily in a 5-foot seam, are reckoned to produce 90 tons of run of mine coal each per shift. The cost of the electric plant is given as about £3300, and of the boiler plant £800. The total cost of machine-getting is given as 2s. 2d. approximately, as compared with 2s. 11d. for hand-mining. The author also discusses § coal-cutting machines generally.

Breaking-Down Appliance.—J. Tonge || describes his hydraulic appliance for breaking down coal after holing. It consist of a cylinder 18 inches long and 3 inches in diameter, with transverse rams forced out by water from a portable force pump.

Working Coal.—A. Nobel and N. Nisbet ¶ give some notes on coal-mining, and include a description of long-wall workings at Broomhill Colliery, and bord and pillar workings at Tanfield Lea Colliery. A comparison is also made between hand-getting and coal-cutting machines.

A description is published of the method used in the Kreuzgräben-grube, near Saarbrücken, for mining two coal-seams, one of which lies close above the other.**

* Report of the Inspector of Mines of Ohio for 1896, through the *Engineering and Mining Journal*, vol. lxiv. pp. 154, 217.

† *American Manufacturer*, vol. lx. p. 661.

‡ *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xiii. pp. 208-212.

§ *Ibid.*, pp. 164-170.

|| *Transactions of the Manchester Geological Society*, vol. xxv. pp. 267-271, with plate.

¶ *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 141-146.

** *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlv. p. 212.

H. Gutmann* deals at some length with the mining of the thinner seams of coal in the United Kingdom. The Newcastle, Durham, and Staffordshire fields are chiefly considered, and the methods of mining in use described at some length.

Safety-Dam.—A detailed description has been published,† with eleven illustrations, of the ingenious portable safety-dam invented by Richard Wagner, of Michalkowitz, Upper Silesia. The importance of restricting an underground fire to a confined area is obvious. The portable dam can be set up in five to ten minutes, and requires only four men. It consists of two parts, the dam proper and the inflator. The former consists of a frame with four folding legs serving as a support for a bag of durable air-tight material resembling an air-cushion, which, when deflated, wraps round the frame. Air is supplied by a portable double-acting air-pump worked by hand.

Pumping Appliances.—E. Briart‡ describes the underground pumping plant at the Catherine shaft of the Bascoup Colliery, Belgium. The leading dimensions are as follows:—Diameter of steam-cylinder 26·38 inches, of pump 6·88 inches, stroke 25·59 inches, diameter of rising main 5·78 inches, of steam-pipe 5·58 inches, of condenser 12·60 inches. The engine runs at 45 to 50 revolutions per minute, and lifts the water 1180 feet. At 45 revolutions the engines developed 109 horse-power. The water before entering the pump passes through the condenser. Plans and elevations of the plant are appended.

At the Engineering Congress of the Institution of Civil Engineers, J. B. Simpson discussed the subject of dealing with water in pits during sinking and in permanent work; and H. Davey gave an account of the methods of draining deep mines.

The Ventilation of Collieries.—Rev. G. M. Capell§ discusses the increase of fan gauges in mine ventilation of the present day, and gives some notes on ventilators. In 1878 the highest gauge was under $3\frac{1}{2}$ inches, with Guibal fans, and ten years later a Capell fan was run up to $5\frac{1}{2}$ inches gauge. Next year this was run up to 9 inches, and

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 491-494 and 508-512.

† *Glaser's Annalen für Gewerbe und Bauwesen*, vol. xli. pp. 123-128.

‡ *Revue Universelle des Mines*, vol. xxxviii. pp. 172-184.

§ *Transactions of the Manchester Geological Society*, vol. xxv. pp. 194-206, with one plate.

a drift gauge of nearly 11 inches was obtained a little later. From that time gauges of 8 to 10 inches have become common. The increasing size of mines, and the increased rubbing surface and leakage, necessitate higher gauges, but up to the present a Capell fan working near Sheffield at the Woodthorpe Colliery gives in regular work 7 inches, and this appears to be the highest in this country. It is suggested that high speed air currents may be used to sweep dust out of the roads. The author's latest forms of fan have inner scoop-shaped blades, and have attained a great measure of success, and several of them have been and are being built to give gauges as high as 12 inches.

H. W. Halbaum * gives some notes regarding mine ventilation by furnaces.

Safety-Lamps.—Chesneau † describes some safety-lamps with E. Guichot's re-lighting attachments, and some tests of them made in explosive mixtures. In lamps burning oil, the attachment consists of a cylinder embedded in the reservoir, and provided with matches radially arranged, and advanced by a ratchet and pawl, so as to strike a roughened surface. In mineral oil lamps, an amorce strip wound on a roller is carried past the wick, and is struck by a trigger. Both of these acted effectively in lighting the lamp. The second was tested in a current of explosive mixture. Gas burned inside the lamp, but did not explode the amorce.

A series of experiments with the igniting apparatus of benzol safety-lamps is described.‡

Testing for Fire-Damp.—P. P. Bedson § describes the Shaw gas tester, and the method of using it. In the discussion, some of the points which require attention to produce correct results were brought out.

A. H. Wood, inspector of mines, of Tennessee, in his annual report states that every effort has been made to induce the managers of fiery collieries in the State to abandon the Davy lamp for testing for gas. The miners, however, refuse safer types of lamp, and the inspector recommends that the use of the Davy lamp should be pro-

* *Colliery Guardian*, vol. lxxiv. p. 663.

† *Annales des Mines*, vol. xi. pp. 250-258, with illustrations.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlv. pp. 249-269.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 350-355.

hibited by law, as is the case in the Pennsylvania bituminous coal-mines.

J. Coquillion * gives the main provision of the special French regulations concerning fiery mines as follows:—"The fire-damp content in the return airways shall be taken daily in mines unquestionably subject to fire-damp, and at least once a week in those but slightly so subject, the observations being recorded in a book on the day that they are made. Every fiery mine must be provided with two fire-damp indicators and an apparatus for making quantitative analyses of the air. The indicators must record a content of $\frac{1}{4}$ per cent. of the dangerous gas; and their use should not involve greater danger than what may result from the use of safety-lamps of the types adopted." He then describes in detail the apparatus devised by himself for determining the percentage of fire-damp, viz.:—" (1) Apparatus for return airways, giving the fire-damp content correct to within 0.01 per cent.; (2) laboratory apparatus, working with water, permitting an approximation of 0.10 per cent., while it also gives the carbonic acid and oxygen contents; (3) the U-burner, working with mercury, and permitting an approximation of 0.2 per cent.; and (4) the portable indicator, that may be used in the mine, and practically gives results correct to within $\frac{1}{4}$ per cent." All these are of the eudiometric type.

C. Pixis † describes a fire-damp detector in which diffusion through a porous diaphragm increases the pressure inside an enclosed vessel, and this pressure is used to raise a plug which completes an electric alarm circuit.

R. Jeller ‡ describes an apparatus for estimating small quantities of marsh-gas and other gases in the air of coal-mines. It is somewhat complicated, and made on the Hempel principle, but filled with water instead of mercury. The difference in pressure is noted before and after treating the gas with absorbents or submitting it to combustion.

E. Harzé § describes an ingenious instrument for sounding an alarm-bell when a rapid fall of the barometer takes place. The instrument can be adjusted according to the condition of the mine and the apprehensions of the manager. It should undoubtedly prove of value in fiery mines.

* *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 60-70, with one plate.

† *Engineering and Mining Journal*, vol. lxiii. p. 331.

‡ *Zeitschrift für angewandte Chemie*, 1896, pp. 692-702.

§ *Annales des Mines de Belgique*, vol. ii. pp. 269-273.

E. Hankus* has investigated the influence of the height of the barometer on the escape of gas in collieries, and also the analysis of the samples of gas collected. Previous investigations have shown that with a falling barometer the percentage of marsh gas in a colliery increases. The author's experiments agreed with this, as the following results show. About two hundred samples of gas were taken, and always at one and the same point in the colliery, where the percentage of marsh gas usually averaged about one. The following were the results observed:—

Height of Barometer. Millimetres.	Percentage of Marsh Gas.
730·0 to 735	1·20
735·5 to 740	1·15
740·5 to 745	1·08
745·5 to 750	1·04
750·0 to 755	1·00

Small irregularities are often observed, but these are probably due to variations in the air current passing through the mine.

The author's analyses have shown him that even though the samples be not analysed till after eighteen days, using the Winkler method, the percentage of marsh gas in the gas mixture remains constant, although the carbon dioxide diminishes slightly, as is but natural, seeing that some moisture is always present. Another, and an important observation, is that exceptionally the whole of the methane may entirely disappear, due, as the author's analyses make him confident is the case, to organic matter in contact with the gas, a brown or greenish-brown deposit being formed on the sides of the vessel. The metal vessels used in the ordinary Winkler test should therefore be replaced by glass ones, and if these are kept thoroughly clean and air tight, the analysis can be made satisfactorily even after the lapse of several days.

According to F. Clowes,† carbon monoxide gives a distinct flame-cap over the hydrogen flame, and this is sufficiently delicate to ensure warning against danger. The lower limit at which carbon monoxide begins to be dangerous (about 0·20 per cent.) is a quantity which produces over the standard 0·40 inch hydrogen flame a cap 0·50 inch in height and distinctly visible. There is the difficulty, however, that a cap may be produced by the presence of any other inflammable gas, as well as by carbon monoxide. A modified form of apparatus

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 548-549.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 71-73, with illustrations.

for applying the hydrogen-flame test has been devised. It does not require the operator to enter the atmosphere to be tested. The air is drawn away by a simple pumping arrangement, and is then made to pass over the hydrogen flame under conditions suitable for measuring the flame-cap. Gauzes are provided if the apparatus is to be used in a mine.

Th. Schloesing * has studied the composition of fire-damp, and finds in the samples he has examined up to 4 per cent. of carbonic anhydride, up to 0.9 per cent. of oxygen, and from 2.2 to 39.8 per cent. of nitrogen. The oxygen very probably was introduced when the samples were collected. Nitrogen is very variable, and the remainder of the gas consists of marsh-gas, with a certain proportion, ranging up to 2 to 4 per cent., of higher hydrocarbons, such as ethane. The author then investigated the amount of argon contained in the nitrogen. It was always present approximately in the same proportion as in air, though in certain cases it varied somewhat, but it was always independent of the marsh-gas present. It would seem that most of the nitrogen did not come from decomposition of matters constituting the coal. Possibly it is the relic of air of the Carboniferous age, and on this point the author offers some speculations, but does not adhere strongly to any theory. The methods of analysis are given.

The question of the rapid evolution of fire-damp in a mine, and the large quantities that may be evolved daily, is dealt with by Le Chatelier.† That the origin of this gas lies in decaying vegetable matter is generally agreed upon. Mixed with air, the gas forms a detonating mixture. Mixed with less than 6.1 per cent. of gas, air will not explode. The rapidity of the explosion increases as the percentage of gas rises from 6.1 to 12.0 per cent., and it diminishes again from 12.1 to 16 per cent. Dangers from explosions are to be met by improved ventilation and the use of safety-lamps, together with the other well-known precautionary measures.

Colliery Explosions.—E. Edwards ‡ describes the explosion which took place at the Maindy Pit of the Ocean Coal Company, Wales, in November last year—an occurrence that was extraordinary in that no one was in the pit at the time. Ventilation doors were blown down,

* *Annales des Mines*, vol. xi. pp. 5-37; *Comptes Rendus*, vol. cxxii. pp. 232, 302.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 579.

‡ *Journal and Proceedings of the South Wales Colliery Association*, 1896, pp. 13-23. A lengthy discussion confirming the opinions expressed above is reported in subsequent numbers.

the timbering destroyed, and heavy falls of roof took place over considerable lengths of roadway. It seems to be tolerably certain that gas had accumulated, and was fired by a spark produced by the friction between masses of falling rock. Pieces of the rock which fell had this property of giving sparks when rubbed together.

For the purpose of saving life in colliery explosions, E. J. Bailey* recommends that compressed air should be laid on to a number of points in the mine, so that fresh air would be accessible after an explosion, and the loss of life which is so largely due to after-damp might thus be obviated.

According to H. Le Chatelier,† there are two methods of obviating fire-damp explosions: (1) To have ventilation sufficient to keep the proportion of fire-damp less than 6·1 per cent.—indeed, to ensure absolute security the percentage should be kept below 0·5, so as to guard against slow disengagement of gas; (2) to use well-designed safety-lamps. Management plays the most important part in lessening colliery accidents. A manager should not only be thoroughly competent, but also be in touch with his men. He should pay frequent visits to the workings, and see that the precautions laid down by law are carried out. Incidentally the author mentions that safety-lamps burning acetylene have been used, two lamps having been constructed with burners made of rubies perforated with fine holes. The light given is of one to two candle-power.

Coal-Dust in Mines.—Dröge ‡ discusses the methods of obviating the dangers associated with coal-dust and of dealing with blasting in the Saar coalfield.

Mine Fires.—L. Champy§ gives an account of the fire in the Hermengilde pits in Austrian Silesia, in which several lives were lost. It appears to have been caused by the electric lighting wires, either from a fuze or from the breakage of their somewhat defective protection and insulation. Since then the wires have been better protected in the district. Owing to the men who discovered the fire leaving the separation doors open, the smoke obtained access to the

* *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 133-139, with one plate.

† *Mining Journal*, vol. lxxvii. p. 787.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im Preussischen Staate*, vol. xlv. pp. 165-202.

§ *Annales des Mines*, vol. xi. pp. 219-227, with one plate.
1897.—ii.

downcast shaft, and thus led to the loss of several lives. At first the air current was increased, but ultimately the shafts were closed, and after some time the fire was extinguished with water.

E. H. Coxe and C. H. Thompson * describe the fire in a colliery in Trimble Township, Athens County, Ohio. The output of the colliery was 1400 tons daily from a seam about 8 feet in thickness, and the shafts are 111 and 138 feet in depth. Probably the fire was caused by thawing a frozen rising main from the pump by burning oily waste around it. The men were all removed and the shafts covered for about a month, after which they were opened and the fans re-started cautiously. The fire was then found to still exist in the roads near the pit bottom, and the authors describe in detail the methods of carrying bratticing forward and working round the dangerous spots, so as to extinguish the fire with hose-pipes and stopping off several sections.

The History of Coal-Mining.—R. L. Galloway † has continued to publish further instalments of his comprehensive history of the British coal trade.

W. F. Willoughby ‡ compares the mining legislation in the different States of the United States. Of the forty-five States and three organised Territories, twenty-four do not possess special laws relating to coal-mining, four have only partial laws, and the remaining twenty have elaborated more or less detailed codes and regulations. To a considerable extent these follow one model, and they are considered generally under several headings ;—women and children's work, length of the working day, mine regulations proper, examination of mine and fire bosses, reporting of accidents, inspection of mines, and payment of wages.

Mine Surveying.—The old hanging-compass is still largely used for mine surveys on the Continent. As in this method of surveying both the compass and the clinometer are suspended from a stretched cord, the weight of the instruments is a matter of great importance. The improvement introduced by a Vienna firm of making the compass and clinometer of aluminium instead of brass consequently merits attention. The weight of a clinometer reading to 1°–6° is in brass 3½ ounces, and in aluminium 1·3 ounces. The weight of the hanging-

* *Engineering and Mining Journal*, vol. lxxiii. pp. 511–512.

† *Colliery Guardian*, vol. lxxiii. pp. 719, 761, 805, 853, 900.

‡ *The Mineral Industry*, vol. v. pp. 633–640.

compass is in brass 47 ounces, and in aluminium 20 ounces. The difference in price between the outfit in aluminium and that in brass is 10s. to £1.

K. E. Weiss * describes the process of connecting the surface and underground surveys by means of plumb lines suspended in two vertical shafts, and P. Uhlich † publishes a mathematical study of plumbing in a vertical shaft.

J. Němeček ‡ describes a method of surveying steeply inclined workings, with dips of 70° and upwards. He deals with cases in which the use of the theodolite is excluded.

C. Tappan § prefers to use a light and small transit, weighing with the tripod about 12 lbs. A prismatic eye-piece is used to take direct observations on the sun, and the formulæ used are stated. The length of the chain to be used is also discussed, and some hints are given.

L. Litschauer || refers to the necessity for accurate plans in mining. He shows that at first mine plans consisted merely of a series of lines, all quite alike, and could only have been of value to those who actually made them. Subsequently these lines and strokes had signs, letters, or numbers with explanatory remarks as well, and they thus became of value to others besides their originator. The collection of plans at the Mining Office at Herrengrund in Hungary is of much interest, as showing the gradual improvement made in such plans. The author refers to an interesting and important order issued in 1834 by Gabriel Svaiczner of Schemnitz, who required that all mine plans should show not only the workings themselves, but the kind of rock passed through, the faults, cross-courses, and the local conditions generally. The author shows how important it would have been for present working had the above instructions been thoroughly carried out, especially as regards old workings which are not now accessible. He then enumerates in detail the points required in connection with mine plans. A. von Péch considered that at least five sheets are required, showing the general character of the neighbourhood, a general view of the mine workings, a detailed plan for each level, a vertical section, and a plan of the workings.

* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1896, pp. 101-102.

† *Ibid.*, pp. 112-130.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 465-467; six illustrations.

§ *Engineering and Mining Journal*, vol. lxiv. p. 244.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 233-236 and 252-257; ten illustrations.

Collieries in Great Britain.—Detailed descriptions have been published in the *Colliery Guardian* of a number of British collieries. The list includes the following in the Lanarkshire coalfield: Carmyle Colliery (vol. lxxiii. p. 672), Easterhill (p. 672), Udston (p. 252).

The collieries in the Ayrshire coalfield described comprise: Annandale (vol. lxxiii. p. 855), Caprington (p. 854), Fairlie (p. 855), Fergus-hill (p. 732), Gauchalland (p. 762), Holmes (p. 807), Springhill (p. 732), and Windyedge (p. 855).

The collieries in the Yorkshire coalfield described comprise: Morley Main (vol. lxxiii. p. 945), Newmarket (p. 1129), Park Farm (p. 989), Victoria (p. 989), Foxholes (vol. lxxiv. p. 16), Thornhill (p. 60), the West Yorkshire Iron and Coal Company's collieries (p. 151), Park Mill (p. 193), Wombwell Main (p. 237), North Gawber (p. 284), Woolley (p. 331), and Waleswood (p. 374).

The colliery in the Derbyshire coalfield described is Shirland (vol. lxxiv. p. 571).

The collieries in the South Staffordshire coalfield described are Great Wyrley (vol. lxxiv. p. 647) and Coppice (p. 737).

Detailed descriptions have also been published * of the Dowlais Iron Company's new colliery, of Deep Navigation Colliery, and of the Great Western collieries. Some features of the South Wales coalfields are also described.†

In a presidential address G. A. Mitchell ‡ deals with the question of economy in mining, and gives a number of illustrations to show the relation between capital expenditure, interest, output, and time.

The Rive de Gier Collieries.—E. de Billy § gives the history of the Rive de Gier collieries in the St. Etienne district, where the workmen formed a co-operative association for working the coal. The collieries had been worked from the middle of the century, but since 1881 the output largely diminished, from 210,000 to 75,000 tons in 1886, partly owing to the exhaustion of the coal and to great difficulties from the large quantity of water. There are lower beds that have not been worked, or even opened up, as they should have been, and a very considerable quantity of coal might have been extracted from the seams that were opened. Nevertheless the pumps were stopped and dis-

* *Iron and Coal Trades Review*, vol. lv. p. 126.

† *Ibid.*, pp. 162, 275.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 216-226.

§ *Annales des Mines*, vol. xi. pp. 38-88.

mantled and the pits drowned. The workmen then combined, reviving a syndicate that had been formed in 1878, and after some public agitation they began to work on their own account. In February 1887 there appear to have been 127 members and 40 candidates. Later on the syndicate was enrolled as a company, but for a considerable time there were strenuous fights in the law courts between the new and the old company. The latter held the concessions, and had not formally surrendered them, so they considered themselves as liable for any damage that might be caused by surface workings, which the men at once attacked, besides which there was a possibility that they might recommence working. Besides this, the company had made over concessions to which they had only a partial right, and the lessees and other owners naturally objected. In 1891, however, the workmen's company became the proprietors of certain abandoned concessions, ten in number. Nevertheless their troubles were not over, owing in part to the attitude of the original company, and in part to internal dissensions. Difficulties as to payment for surface damage had to be settled, and then the constitution of the company led to serious quarrels. The members included miners working in adjacent collieries, and, of course, these objected to the wages that the working members allowed themselves, and to the general conduct of the concern; so the working members, seventy-one in number, excluded the forty-nine non-working members during 1889. Then appeal after appeal to the courts and to the public did not improve matters. The author then deals with the various mining operations which were carried on by the men. Most of the work appears to have been confined to robbing the pillars. In ten years about 80,000 tons of coal was won by an average number of fifty-six men. The balance-sheet [shows a loss of about two shillings a ton, but against this is set off the wages drawn by the workers, and the deficit was covered by subscriptions received from time to time. The results do not offer much promise for future co-operation. The difficulties to be surmounted have been undoubtedly great, and the greatest of them all has been the want of capable direction and the lack of discipline.

Coal-Mining in Alabama.—Some particulars of coal-mining in Alabama have recently been given in a historical pamphlet issued by the Tennessee Coal, Iron, and Railway Company, and a photographic illustration taken from this pamphlet has been reproduced * to show a

* *Engineering and Mining Journal*, vol. lxiii, p. 574.

section of the John's coal-seam at a mine where the output is 800 tons daily, and the product is washed in a double Robinson coal-washer.

A photograph has been published * of the works of the Hargrove Colliery in Alabama. The incline is, according to W. M. Brewer, 1000 feet in length, and the capacity of the mine is 400 tons per day. The coal-seam is 5 feet thick, and has a good slate roof. The product is a good steam and household coal. At the surface the coal is raised up a high angle, and tipped without loosening the trucks from the chains. The cost of mining is 1s. 8d. per ton, no convict labour being used.

Subsidence Caused by the Working of Mines.—W. Galloway † gives a resumé of the most important papers and reports which have appeared on the subject of subsidence caused by the working of mines. The vertical theory and the normal theory, in which the breaks are supposed to be at right angles to the strata instead of truly vertical, are mentioned, Dumont's researches on the latter being dealt with. Then the results of Fayol's researches and experiments are given in greater length, with numerous illustrations. The conclusion of the latter is that the movements of the ground are limited by a kind of dome, which has for its base the area of the excavations; their amplitude diminishes by degrees as they extend farther away from the centre of that area.

IX.—COAL-WASHING.

Screening Coal.—W. H. Mungall ‡ describes the screening appliances at Mossbeath Colliery, and gives a plan and elevation of the plant. The three tippers are of the revolving geared type, with an automatic knock-off. The coal from the tippers falls on distributing bands, which lead it to fixed bar-screens, whence it drops on to two German picking belts 4 feet wide, built up of transverse rods $\frac{3}{4}$ -inch in diameter, and spaced $\frac{5}{8}$ inch apart. These belts are 18 feet long, and are hinged near the middle to reduce the drop into the railway trucks. A third picking band is of the plate type, and delivers coal on to a perforated jiggling screen, from which the dross is led away by

* *Engineering and Mining Journal*, vol. lxiv. p. 11.

† *Proceedings of the South Wales Institute of Engineers*, vol. xx. pp. 304-342.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 227-230, with one plate.

a cross-band. The dross from the fixed bar-screens is converged to a compound jigger, making three sizes, of which the nuts are picked on a fourth German band. Single nuts pass direct to railway waggons, and duff is led to the boilers. The substructure of the screening plant is built of old rails.

Parent* gives a description of the pneumatic appliances in use for separating dust from small coal so as to avoid the difficulties which the dust causes during washing. Several of these appliances are in use, and those at the Rheinpreussen, Zollverein, and St. Louis, Anzin, collieries are described, and also the Lagrange method. An air-blast from a fan is caused to meet the coal as it falls from the trommel, and the finer portions are settled in settling chambers or dust separators, which may make several sizes. Figures are given to show that there is a considerable economy in washing due to the separation of the dust.

Some of these appliances are also referred to by R. Cremer.†

In the Transvaal, according to W. T. Hallimond,‡ only two sizes of coal are made, viz., round and nuts, whilst the dust is all thrown on the waste-heaps. At the Rand Colliery jigging-screens 20 feet long are used with bevelled bars spaced $\frac{3}{8}$ -inch apart. The nuts and small fall on to a screening gauze of $\frac{3}{8}$ -inch mesh to separate the dust. Long sorting belts are necessary for picking the coal. All coal has to be bagged, and for this purpose the shoots are subdivided. Formerly the coal was discharged on to a flat tray, whence it was shovelled into the bags. Side-revolving tipplers are used, and the tubs hold 20 cubic feet. The head-gear at the colliery is also described, and illustrations of the plant are given, with a plan and elevations of the surface plant.

Washing Coal.—R. Cremer§ discusses the present practice of washing coal in Germany and England. German collieries generally employ geared steel rolls for breaking the coal. Disintegrators of the Carr type are in use in both countries. For sizing the coal Knepper's improvement on Briart's screen by the use of perforated channel iron is mentioned, together with other screening appliances of various types. The felspar type of washer still holds its place, but different improvements in Lührig's system have been introduced. Amongst these are Baum's pneumatic jig and Sheppard's washer. Trough-washers, with

* *Annales des Mines*, vol. xi. pp. 123-128, with one plate.

† *The Mineral Industry*, vol. v. pp. 160-162.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 372-380, with illustrations and one plate.

§ *The Mineral Industry*, vol. v. pp. 153-165.

movable riffles and with travelling troughs, are also in use. The pneumatic separation of dust by an air-blast has afforded a considerable improvement. Clarification of the water and the storage and drainage of washed coal are also dealt with. Finally, the author gives a short description of the washer at the Zollen Colliery, and at the Minister Stein Colliery, near Dortmund. The various appliances referred to are illustrated by seventeen figures.

R. H. Richards * gives abstracts of the principal descriptions of coal dressing and washing plants that have recently appeared.

R. M. Hosea † gives an illustrated description of the Colorado Fuel and Iron Company's washing plant at Sopris. The main parts of the plant and the horse-power used for running them at full capacity are as follows:—Inclined conveyor, 20; bucket elevator, 20; two sizing screens, 6; toothed rolls, 20; ten jigs, 10; three cross-conveyors, 3; centre conveyor delivering to disintegrator, 2; and centrifugal pump, 18: total, 99 horse-power. As water is scarce, very complete arrangements are made for draining the coal and settling the muddy water in reservoirs. The drainage from the coal is led through a trough with riffles in the bottom, which catches some dirt, whilst the finer portions which settle later are saved as coal. Breeze made at the coke-ovens is returned to the disintegrator, and put through the washing, so as to mix with the coal.

F. M. Jackson ‡ gives an account of the Brookwood washer in Alabama. It is a modification of the Lührig system, all the coal being crushed to a size not exceeding $\frac{3}{8}$ inch before washing, and the jig beds being made longer, in some cases up to 16 feet. The ash is reduced from 13 or 15 per cent. down to 8·80 on the average, and sulphur from 1·50 or 1·75 to under 1 per cent. Loss of coal averages $6\frac{1}{2}$ to 9 per cent. There are eleven double compartment jigs with three sizes of jigs and screens, five being $\frac{3}{8}$ inch, three $\frac{3}{4}$, and three $\frac{1}{2}$ inch. The best results are obtained from the fine and medium sizes. The capacity is 560 tons daily. A plan and elevation of the plant are given.

The coal-washing plant § at Lens, in France, is of the Schüchtermann-Kremer type, and comprises six jigging machines and twenty felspar washers. It treats 110 tons an hour. The raw material is brought from

* *The Mineral Industry*, vol. v. pp. 727-730.

† *Colliery Engineer and Metal Miner*, vol. xvii. pp. 478-480, 521-524.

‡ *Proceedings of the Alabama Industrial and Scientific Society*, vol. vi. pp. 50-54, with one plate.

§ *Echo des Mines*, vol. xxiii. pp. 2246-2247.

the various shafts in lumps up to 25 millimetres (0·98 inch). The coal-dust up to 3 millimetres (0·12 inch) is screened off and passes to the coke-ovens. The stuff above 3 millimetres is divided into four classes :— (1) The finest of 3 to 6 mm. is treated in ten felspar washers; (2) the fines of 6 to 10 mm. in nine similar machines; (3) lumps of 10 to 18 mm. pass to four jigging machines; and (4) lumps of 18 to 25 mm. pass to two other jigging machines. From 100 parts of coal there are obtained 25 parts of dust, 38 parts of washed fines of 3 to 10 mm., 28 parts of washed lump, and 9 parts of shale.

E. Depoitier * gives drawings of the new coal-washing plant installed at the Hazard Colliery, Belgium. It is arranged to treat 400 tons in ten hours.

The Wunderlich coal-washing plants are described by V. Waltl.† In the Kladno district eleven such plants are in operation, and these treat 200,000 tons of coal. The plants are of two kinds. In one of these a subsequent secondary washing is adopted, the plant being practically duplicated. In the others such double treatment is not adopted, a combined method being used instead. The plants are described and illustrated, and details are given as to their cost in practice and the results attained by their use.

C. E. Bowron ‡ describes the coal-washing and coking plant at Tracy City, Tennessee, which consists of screens, a 400-ton Robinson washery, a 500-ton disintegrator plant, a 500-ton drainage-bin, 204 beehive ovens in six batteries, including one battery of flue-ovens. The screens are vibrating perforated plates. Screw conveyors are largely employed for moving the coal. A list of nineteen plants using the Robinson washer, and having a capacity of 7200 tons daily, is given as existing in Tennessee, Alabama, and Georgia. A plan and elevation of the plant is appended.

An exterior view has appeared § of a Jeffrey Robinson washing plant erected for making tests on truck-loads of coal.

Two illustrations have appeared || of the type of Robinson washer which is being erected at several points in the United States.

* *Annales des Mines de Belgique*, vol. ii. pp. 741-745.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 357-358; two illustrations.

‡ Sixth Annual Report of the Bureau of Labour Statistics and Mines of the State of Tennessee, through the *Colliery Engineer*, vol. xviii. pp. 57-58.

§ *Colliery Engineer*, vol. xviii. p. 59.

|| *Iron Trade Review*, vol. xxx. No. 26, p. 11.

Loading and Unloading Coal.—During the summer meeting of the Ohio Institute of Mining Engineers, special attention was devoted to examining the method of loading coal at various Lake Erie docks. In a report of this excursion the *Iron Trade Review** publishes some photographs of the appliances used. At Sandusky, the crane and bucket system is employed, this being the first to dispense with shovelling. At the Minnesota dock of Ashtabula Harbour, the Brown side-tipping unloader with bucket transfer system is used.

Illustrations have been published† of some modern methods of loading coal.

S. Howard-Smith ‡ gives some illustrations of various appliances used in different parts of the world for coaling steam-ships.

In the plant at Greenville, Missouri, coal is unloaded from railway trucks and transferred after screening into barges on the river. For this purpose hopper trucks with bottom doors are run over a trestle, and drop their contents into a bin holding 50 tons, from which a steel trough conveyor, 4 feet wide, 12 inches deep, and 264 feet long, placed at an angle of 10°, leads the coal to a tippie where it is screened before loading. The large coal is transferred to the barge by buckets holding two tons each.§

Gondola coal-waggon of 60,000 lbs. capacity are being built for the Titusville, Evansville, and St. Louis Consolidated Railway. They are 37 feet 6 inches in length and 7 feet 11 inches in height from the rail to the top of the body. The approximate cost is £73.

Illustrations have been published|| of a large coal-bin which failed at Patterson, New Jersey. It was of trough section with flaring sides, 105 feet long, 32 feet wide, and 19 feet deep. At the time of failure it held about a thousand tons, which poured down over the ranges of boilers placed below. In further articles¶ the designs of this bin, and of others of a similar type, are discussed.

Burning Coal-Dust.—A series of experiments has recently been conducted in New York with the Wegener method of burning finely-

* Vol. xxx. No. 26, pp. 8-10.

† *Iron and Coal Trades Review*, vol. lv. pp. 535-537, 610-611.

‡ *Cassier's Magazine*, vol. xii. pp. 531-540.

§ *Chattanooga Tradesman*, through the *Engineering and Mining Journal*, vol. lxiii. p. 455.

|| *Engineering News*, vol. xxxviii. pp. 142-144.

¶ *Ibid.*, pp. 196-197, 200-201.

powdered coal, a method which has been fully described by Bryan Donkin. Criticising the experiment, the *Engineering News* * thinks the extensive introduction of the system into the United States is very improbable. It is handicapped by the expense of grinding the coal. The space occupied by the grinding apparatus, the uncleanness of the operation, and the double handling of the coal, will all be serious objections to the use of the system.

On the occasion of an excursion made by the Austrian Ingenieur und Architekten Verein † to the Neuman works at Marktl, they inspected the system of coal-dust firing in use there. The works possess two scrap furnaces (rapid puddling furnaces), and three reheating furnaces, all provided with the Schwartzkopf system of coal-dust firing. In the scrap furnaces charges of 0.165 ton are placed, and afterwards hammered into blooms, twenty to twenty-four charges being worked off in the twelve-hours' shift. The works are briefly described, together with the products made. The fuel used in the Schwartzkopf apparatus consists of bituminous coal from the neighbouring Schrambach collieries, but on the occasion of this visit fifteen different kinds of fuel were used. The coal-dust at present used is made at the works in a small Hopf mill, which has now been continuously in use night and day for the last two years, yielding from 0.4 to 0.5 ton per hour. The total cost of grinding is 1s. 2d. per ton. The combustion-chamber in the reheating furnace is lined with the best chamotte firebricks, as the fine ash from the coal-dust acts powerfully on the chamber lining at the high temperature existing there. These bricks are made at Hollenburg in Lower Austria, and the best quality has a melting-point equivalent to No. 34 of the Seger scale. This corresponds to about 1810°. These bricks are found to resist the action of the dust in a satisfactory manner.

M. Caspaar, ‡ in a paper read before the Austrian Ingenieur und Architekten Verein, considers the question of the commercial utilisation of coal-dust. From a technical standpoint the questions that have to be answered are "How large is the quantity of small coal produced?" "What differences are there in quality between the small and large coal in the coal obtained from the same mine?" "What causes lead to a difference in the uses to which the large coal and coal smalls are

* Vol. xxxviii. pp. 189-190.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv.; Beilage, No. 4, pp. 44-45.

‡ *Ibid.*, vol. xlv. pp. 373-377, and 401-405.

put?" "What arrangements admit of, and assist in, the utilisation of the coal smalls?" and "What progress can be observed in the use of small coal?" In addition to these there are the other commercial questions as to how far the increasing use of coal smalls affects the profit of a colliery; how far the variation in price between the different sizes of the same coal is to be explained; and what influence is exerted on this scale of prices by the increasing use of the small coal?

The author deals with these various questions. He shows that there are no available statistics showing what proportion of the total output consists of small and what proportion of large coal. This is doubtless due to the fact that the names given to the same sizes vary locally. It varies, of course, with the nature of the coal and its mode of occurrence. Dealing with an official publication about Austrian coals of the year 1878, the author shows that much information can be gained from this as to the point in question. He takes for the basis of his calculation the following classification—

For Coal.		For Brown Coal.	
Name.	Size.	Name.	Size.
	Inches.		Inches.
Large coal	Over 3·54	Lump coal	Over 3·94
Cubes (or Nuts I.)	3·54 to 1·68	Cubes (middle coal)	3·94 to 1·97
Nuts (or Nuts II.)	1·58 to 0·71	Coarse fines	1·97 to 1·26
Smalls (or Nuts III.)	0·71 to 0·28	Middling fines (nuts)	1·26 to 0·55
Dust	0·28 to 0·00	Fines I.	0·55 to 0·35
... . . . .	...	Fines II.	0·35 to 0·24
... . . . .	...	Dust	Under 0·24

The nomenclature varies somewhat between the two kinds of coals, and the author gives that as customary in Austria, but he points out that not only the names vary locally, but the sizes also. The following are some examples given by the author to show the relative quantities of the different sizes occasionally noticed :—

Bituminous Coal.	Per Cent.
Large coal	15
Cubes	19
Nuts	15
Smalls	27
Dust	34*

* Probably 24, as the total is 110 per cent.

Size.	Brown Coal.				
	Good Quality.			Poor Quality.	
	I. Per Cent.	II. Per Cent.	III. Per Cent.	Per Cent.	
Lump	38	26	15	}	63
Cubes . . . . .	...	...	5		
Coarse fines	18	19	11	}	13
Middling fines	18	22	18		
Fines I.	15	14	15	}	13
Fines II.	9	17	14		
Dust . . . . .	...	...	18	10	

In the case of lignite, the lump coal varied from 51 to 67 per cent., the cubes from 21 to 17, the fines from 15 to 11, and the very fine from 10 to 4. The author gives a large number of other instances, and he thinks that it is certainly beneath the mark if one assumes that the quantity of small coal, less than 0·59 inch in size, amounts to 40 per cent. in the case of bituminous coal, and 20 per cent. for brown coal. This would mean for Austria 3,889,072 tons of bituminous coal and 3,677,829 tons of brown coal per year, on the basis of the output in 1895.

It is not possible either to answer the question whether all the coal raised is utilised, or whether some remains unutilised, except to point out in a general way that the more the use of small coal spreads, the more complete is the utilisation of the coal. For coking coal, the question of the waste of smalls does not enter into discussion. The author deals historically with the question of the use of small coal, and he shows that, apparently in 1894, some of the smaller brown coal was not utilised in Bohemia, and further, that since then this loss has diminished.

In fine coal, as compared with lump coal, there is more slate and other ash, the result being that the fuel value is smaller, and this necessitates a careful mechanical preparation for coal of this size. It is not only the quality, however, that stands in the way of the utilisation of the small coal. It is less easy to burn than the lump, in so far that the finer it is the more difficult is it to introduce among it the air necessary for its combustion. The introduction of step grates and of gas-firing dealt with the difficulty. The high percentage of ash contained in these coal smalls often necessitates a large area of grate in its combustion, and to avoid this the coal should be properly washed before use. The size of the different particles should also be as

regular as possible, and in some methods of firing this regularity of size is a necessity. The difficulties in dealing with bituminous coal-smalls are very much less than in the case of brown coal smalls. The ideal use of small coal lies in the dust-firing methods. This not only yields a smokeless combustion and great economy of fuel, but it enables every particle of every kind of coal to be made available for combustion purposes.

The profit derived from a colliery depends on the first cost of the product raised, and on the best possible utilisation of the different minerals. With the first of these points the author does not deal, but he touches on the matters connected with the second. Competition with wood is not to be disregarded, this depending on the locality. With regard to the calorific value of the coal and brown coal mined in Austria, he observes that this varies from about 7000 down to 2500 calories. Schwackhöfer found as a maximum for Austrian coal 7441 calories, and as the minimum 4032. For brown coal the maximum was 5667, and the minimum 2096.

Of importance in connection with the price of a coal is its value for household use. It must be as free as possible from sulphur, contain little ash, and not be too dirty. It is not possible to say that the price for the different sizes of one and the same coal varies in accordance with any degrees of difference in their calorific value. Coal of as high a calorific power as possible is needed on shipboard, on account of the necessity for keeping down the weight as much as possible. Again, in boiler plants local conditions are all-important in determining the value of a coal. Similar considerations are general in all cases, especially where gas-firing is not employed.

Briquettes.—P. R. Björling * describes and illustrates the machinery used for the manufacture of briquettes.

* *The Colliery Guardian*, vol. lxxiv. pp. 556, 601, 647, 695, 738, 784.

PRODUCTION OF PIG IRON.

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I.—BLAST-FURNACE PRACTICE.

Determining the Relative Reducibility of Iron Ores.—J. Wiborgh * observes that it is customary to say that an iron ore is readily reducible or hard to reduce. This means that it gives up its oxygen with more or less readiness or difficulty as the case may be. The greater the density of an ore, the more difficult it is to reduce, and for similar oxides the reducibility may be stated as inversely proportionate to the specific gravity. Everything which increases the porosity of an ore or opens it up in any way assists in its subsequent reduction. Consequently an ore in a fine state of division is easier to reduce than the same ore in a compact form. By changing the degree of oxidation of an ore a re-grouping of the molecules results, and the reduction is arrested. In a far greater degree is this the case if the ore contains volatile substances which can be expelled by the action of heat, such as water, carbon dioxide, or sulphur, and are driven off in this way. The iron hydrate ores and the carbonates are therefore easy to reduce, and so too roasting facilitates the subsequent reduction of magnetite. Ferric oxide must be more readily reducible than the magnetic oxide, as the author shows, for giving up some of its oxygen more easily to commence with, the ore becomes porous, and the subsequent reduction is rendered easier, and this has been shown in practice to be the case. Ferric oxide, too, under certain conditions, causes the

* *Jernkontorets Annaler*, vol. lii. pp. 280-310.

dissociation of carbon monoxide, separating the carbon, and this in all probability has a most important influence on the reduction. The chemical analysis in itself therefore is by no means adequate for the determination of the furnace character of an iron ore, and it was with a view to ascertain this readily that the author suggested his earlier assay method for this purpose. Since then the method has been further developed, and the author still purposes continuing the investigation in so far as it relates to the deposition of the carbon at different temperatures, with a view to ascertain the part played in the reduction of the ore by carbon monoxide.

The method the author now describes is explained by the aid of illustrations. A kind of gas-producer is used, into which an iron tube can be let down to varying depths. Through this tube the producer gases can be made to pass. The iron ore under examination is charged into this tube. As the gases pass up the tube they become colder, and similarly the descending iron ore becomes hotter, the conditions, therefore, being similar to those existing in a blast-furnace. The producer is really a deep wind-furnace of ordinary sectional area. The fuel used is charcoal, burned on an ordinary grate. Above the layer of fuel are two holes through which air enters, burning the excess of gas. The draught is regulated by means of a valve and a door in the ordinary way. The tube used is of wrought iron, and consists of two parts, a lower tube, 2 inches in diameter, and an upper one of about $1\frac{1}{2}$ inch diameter. To protect them from oxidation the bottom part of the lower tube is protected by a layer of clay and chamotte, kept in position by the aid of an iron ring at the bottom of the tube. The tubes are connected by an iron connection-piece provided with a valve. The reduction-tube is placed in the centre of the furnace, passing through an orifice in the furnace cover. The total length of the tube is about 5 feet 3 inches. The ore to be examined is placed inside a piece of iron gauze, and this is then hung for definite lengths of time at any desired distance down the tube, the ore being just large enough not to pass through the gauze, only that portion of the sifted ore being taken which will pass through a screen having nine meshes to the square centimetre, but not through one having sixteen meshes. The gauze has thirty meshes to the square centimetre. Three or four small gauze cylinders, holding 8 or 10 grammes each, are combined together into one large capsule. This was found far more convenient than using a single 30 or 40 gramme cylinder, and it has too the advantage that it enables three or four different kinds of ores to be

treated at the same time, and also comparison made with some ore taken as a standard. The form of the capsule now used is shown by an illustration. The method of firing the furnace and heating the tube is described. After two hours the producer gases in the tube usually attained their highest temperature. A series of temperature determinations were made by the aid of alloys and of the thermophone. The temperatures varied from 400° C. to 1500° C. as the lower end of the tube was approached. Analyses showed the composition of the gas used to vary as regards carbon dioxide from 3.2 to 3.6 per cent., and as regards the percentage of carbon monoxide from 30 to 32. By raising the bottom of the tube a few inches farther from the fire-bars the percentage of carbon dioxide was reduced to 1.7. If the reduction is effected at too high a temperature, the resulting material consists of a mixture of metallic iron, iron oxides, and carbon, the analysis of which is not the easiest matter. The percentage of metallic iron may be determined by ascertaining the quantity of hydrogen it will evolve when treated with dilute sulphuric acid, while the total iron contents are readily ascertainable by titration. The carbon can be determined by oxidation with chromic-sulphuric acid. The relative degree of oxidation of the reduced ore the author determines by taking 0.4 gramme and treating this with 5 cubic centimetres of sulphuric acid of 10 per cent. strength in a nearly closed vessel. By allowing the acid to react for about half-an-hour to one hour, nearly all the metallic iron will have been dissolved, while only small quantities of iron oxide will have passed into solution, and the reducing action of the hydrogen brought to a minimum. Five cubic centimetres of the strong acid of 1.23 specific gravity is subsequently added, the solution transferred to a beaker, and then titrated with permanganate. It may be necessary to decant the weak acid before treating with the strong one, as some ores are hard to dissolve.

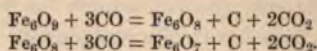
In this way the total iron contents is obtained, and the quantity of metallic iron being known, the quantity of ferric oxide and ferrous oxide is obtained by subtraction. If the total percentage of iron is n , that of the metallic iron r , and that of the ferrous oxide as found by titration m , then the degree of oxidation is found by means of the following equation :—

$$\frac{(m-r) 3}{2} : (m-r) + \left(\frac{(n-r)-(m-r)}{2} \right) 3 = 100 : x.$$

$$x = \text{degree of oxidation} = \left(1 - \frac{m-r}{3(n-r)} \right) 100.$$

The author calls the degree of oxidation of ferric oxide 100 ; that of the magnetic oxide 88·9 ; and that of ferrous oxide 66·7. He observes that if ferric oxide is considered as $3\text{Fe}_2\text{O}_3 = \text{Fe}_6\text{O}_9$, and if from this one molecule of oxygen is gradually withdrawn, four oxides are obtained instead of three, a new one Fe_6O_7 , with an oxidation degree of 77·8 coming in between the magnetic oxide Fe_6O_8 and the ferrous oxide Fe_6O_6 .

The author takes as his measure of the reduction the quantity of reduced iron expressed in per cent. of the total iron contents in the ore. The ores examined by the author were in part ores which had been specially obtained for the purposes of the tests, and partly the same samples as were used by Tholander * in 1873 in his investigations on the influence of calcination on the reducibility of iron ore. A portion of these latter were, however, first sifted off, as they were too finely divided for the author's use. In all, thirty-one experiments were made, in addition to some preliminary tests. The results obtained are tabulated. Bilbao ore was taken as the standard ore. It is extremely easy to reduce, as the author shows. It seems to decompose carbon monoxide very readily and to separate carbon. That this separation of carbon is combined with a reduction of the ore is evident, and, as one of the author's experiments shows, even at so low a temperature as 420° the degree of oxidation of the ore can be reduced to Fe_6O_7 , at which it probably remains. As, however, the quantities of carbon deposited are very variable, and occasionally very large, a re-oxidation of a portion of the partially-reduced oxide is most probable, possibly in accordance with the formula :—



This re-oxidation is accompanied by the evolution of heat. The result is that the temperature rises, and when it has reached a certain point the process ceases, and an opposite reaction commences, this being the oxidation by carbon dioxide, as shown by the formula $\text{Fe}_6\text{O}_8 + 2\text{CO}_2 = \text{Fe}_6\text{O}_9 + (\text{CO} + \text{CO}_2)$, which again causes cooling, with the result that a reduction process begins, accompanied by the deposition of carbon. The quantity of carbon deposited does not, therefore, depend on the degree of reduction, but only on time, temperature, and the character of the ore and gas. Experience shows that the temperature must be low, and the iron oxide soft and porous, if carbon monoxide is to reduce

* *Jernkontorets Annaler*, 1874.

it with the deposition of carbon. This is shown, too, in the author's own experiments. If a deposition of carbon results, this must act as a strong reducing agent as soon as the ores attain a higher temperature, as the carbon is extremely finely divided and in contact with the oxide. It is found in the author's experiments that the percentage of metallic iron in the reduced ore increases with the percentage of this carbon in the reduced ore, as the following results show :—

Number of Tests.	Percentage of Carbon.	Degree of Reduction.
6	0 to 1	70 to 82
6	1 to 2	83 to 86
4	2 to 3	85 to 86
2	4 to 6	90 to 93

Another proof in this direction was afforded by a test in which the iron ore was lowered immediately to the point of maximum temperature, 875° C., and kept there for two hours. In this case there was no sign of a deposition of carbon, and the degree of reduction attained was not so high as in several other instances in which the ore had been lowered gradually and then kept at this high temperature for only half the time.

The maximum percentage of deposited carbon noticed during these experiments was as much as 12.23. This resulted in the case of an experiment in which the maximum temperature reached was as low as 700° C. The degree of reduction of the Bilbao ore was slight, having been but 46.5 per cent. The author considers that the carbon was deposited at the temperature of about 400° C in an unusually large quantity, and that the temperature was subsequently too low to cause much diminution in it.

The author gives the results of a number of comparative tests of this Bilbao ore with other ores he names. He also tabulates them under the different headings of hæmatites, magnetites, &c. In his concluding remarks, the author again reverts to the question of how the reduction is effected. The oxide Fe_2O_3 referred to by Wedding was frequently observed. This has the degree of oxidation 77.8. If Bilbao ore was reduced for two hours at the temperature of 400° C., its degree of oxidation was found to be 77.7, without metallic iron being present. In another case, calcined Nyång magnetite treated at 850° C. was found to contain only small quantities of metallic iron, but its degree of oxida-

tion was 77.5. Gellivara ore gave similar results. As soon as the degree of oxidation of 77.8 is passed, a large quantity of metallic iron may be formed before the degree of oxidation of 66.7 is reached. The author, therefore, considers that this oxide Fe_2O_3 is reduced direct to metallic iron, in accordance with the reaction $\text{Fe}_2\text{O}_3 + 7\text{CO} = 6\text{Fe} + 7\text{CO}_2$, ferrous oxide not being formed provided no deposited carbon or hydrogen is present. These reducing agents act somewhat differently to carbon monoxide, leading to the formation of ferrous oxide before the stage of metallic iron is attained.

The Dimensions of Blast-Furnaces.—M. Pierronne,* engineer at the Briansk Company's Alexandra Works, has given in graphic form the relative dimensions of a number of blast-furnaces. Expressed in a tabular form the comparison is given below. The furnaces referred to are—A, Marchiennes No. 2; B, Alexandra No. 1; C, Monceau-sur-Sambre Nos. 1 and 2; D, Ilsede No. 1; E, Pompey; F, Alexandra No. 4; G, Witkowitz; H, Edgar-Thompson type. The particulars given are—I., volume in cubic feet; II., total height in feet; III., ratio of height of boshes to total height; IV., ratio of diameter of throat to height; V., ratio of diameters of throat and boshes; VI., ratio of areas of boshes and crucible; VII., angle of boshes; VIII., inches of pressure of blast; IX., temperature of blast $^{\circ}\text{C}$.; X., iron in ore per cent.; XI., consumption of coke, lbs. per ton of iron; XII., total production per day, tons; XIII., production per cubic foot, tons in twenty-four hours; XIV., capacity in cubic feet per ton of iron per twenty-four hours.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.
A. .	547	51	45	30	60	13	70	5.8	400	34	2570	99	1.30	88
B. .	706	55	39	30	60	15	71½	8.6	680	57.5	2570	90	1.22	79
C. .	741	51	39	31	74	11	71	5.9	440	34	2340	72	0.97	77
D. .	918	53	41	33	81	14	68	5.9	440	44.5	1810	98	1.00	60
E. .	953	62	33	29	85	16	69½	5.9	800	33	2690	74	0.80	124
F. .	1200	67	37	29	66	22	72	9.4	590	57.5	2240	154	1.25	78
G. .	1271	67	35	28	72½	29	70	...	...	...	...	...	...	...
H. .	1885	79	38	28	69	23	75	18.5	620	62	1830	330	1.82	56

These figures are read from the diagram and turned into English measures, and should be taken as only approximate. These factors are then discussed, and from them it is shown that No. 4 Alexandra

* *Revue Universelle des Mines*, vol. xxxix, pp. 81-82, with plate.

furnace F might approach the American production by enlarging the crucible and increasing the blast. The No. 1 furnace B is too low to have a greater blast pressure, but its crucible might be enlarged.

The Société Anonyme des Forges et Aciéries du Nord et de l'Est at Jarville, near Nancy, is erecting a blast-furnace, the height of which is to be 88½ feet. It is stated * that this will be probably the largest blast-furnace on the Continent.

Handling Material at the Blast-Furnace.—A. Sahlin † deals with the question of getting the material to the blast-furnace and removing the product promptly, cheaply, and regularly, in view of the increasing capacity of the furnace. For this purpose several of the modern plants are described. Elevated railway tracks over the stock-yards naturally led to the use of hoppers, from which raw material could be drawn off below, but generally, owing to faulty design, they have not attained much success, and, after all, the hoppers can hold only a limited quantity. The Cardiff Dowlais works have behind the furnaces two rows of hoppers, 30 feet in diameter and 60 feet high, with water counterweighted hoists for the waggons at the ends. This system is better adapted to 10-ton trucks than to 30-ton trucks as in America. In plants requiring large storage capacity, the trestles are very extensive, and good haulage arrangements are necessary. At the works of the Maryland Steel Company at Sparrow's Point, the stock-house is a steel structure 1180 feet long and 100 feet wide, with four lines on trestles 20 feet high, extending 600 feet beyond the stock-house, where foreign ore is stored. The furnace hoists are of the ordinary platform type, 12½ feet square. A narrow-gauge depressed track is laid along the front of the house and beyond the trestles, and on it run trolleys driven by 6 horse-power electro-motors supplied from an overhead conductor. These trolleys carry two transverse tracks, level with the floor under the trestles, and long enough to receive the charging trucks, which are run on them from two tracks under each trestle or bin. Each trolley carries a boy, who runs it to the scales in front of the hoist. The scales and hoists each have two tracks, and between them is a reciprocating transfer-table with six tracks, spaced so that four at each end of the stroke correspond with the scales and hoists, and the other pair with the return track for

* *Stahl und Eisen*, vol. xvii. p. 887.

† *Transactions of the American Institute of Mining Engineers*, Chicago Meeting, 1897 (advance proof).

empty trucks. Two transfer-tables are used at each furnace, and are worked by a pneumatic cylinder. The charging trucks have drop bottoms, and contain 1680 lbs. of coke or 2240 lbs. of ore or flux. Five persons on twelve-hour shifts handle stock for a furnace making nearly 10,000 tons of iron monthly. At the top of the furnace is one track for each hoist, and the trucks are run on tandem; after discharging the track is tilted to return the empties. The stock was thus dropped at four points, causing the furnace to wear at those points only; so now these tracks are mounted on a turntable which is reciprocated through 45° for alternate charges, so the trucks discharge at eight points.

Pneumatic hoists have been used at various furnaces, and the author thinks that this system might be developed with advantage, but the vast amount of material to be handled is too great to be dealt with by improvements in vertical lifts, and a return to the inclined plane is being made, and larger trucks or skips are used. In most of the recent furnace plants the skip-hoist is used, and the labour of top fillers dispensed with. By means of a double hopper, into the upper part of which the skips are emptied, the stock is undoubtedly distributed with sufficient regularity. At the Lebanon furnaces, a charging skip 7 feet 2 inches in diameter, 7 feet 1 inch deep, with a drop bell bottom and holding 8000 lbs., is hauled up an inclined plane by an engine mounted on the top of the furnace. The trip takes two minutes.

At the Pioneer furnaces, Thomas, Alabama, the charging trucks hold 2000 lbs. of coke or 4500 lbs. of ore. They run on 30-inch gauge lines from the charging-house, 150 feet from the furnace, over a turntable on to the weigh-bridge, and then to the inclined hoist. This is 190 feet long, inclined at 25° , and built up of 7-foot lattice girders. Between the 30-inch gauge rails is a second pair of rails on a gauge of 22 inches, and a pushing-truck runs on this latter into a pit at the bottom, so that the stock truck runs over it and then is lifted to the top. The truck runs over the centre of the bell, and its counter-weighted drop-bottom doors are opened by fixed guides which lift the counter-weights; 5500 tons of stock have been lifted in the week. Double truck lines have also been designed, but are not described.

A brief description with illustrations is then given of some of the appliances for unloading ships and transferring the material to the stockyard, the Brown hoisting and conveying plant being especially mentioned. Reference is also made to wire ropeways and electrically driven conveyor belts. Comparing the methods tried at different

plants and the results obtained, it seems that a combination of some suitable form of the Brown hoisting and conveying machine, with steam-shovels for reloading the ore, hopper storage for coke and flux, electric transfer, and a good form of the inclined skip-hoist, raising a large portion of the charge on each trip, would represent the most effective arrangement at present.

Although the charging side has been so developed, the casting-house remains, as a rule, in its early condition. Iron chills will not be used for foundry iron until it is bought on analysis, but they are valuable for basic iron by eliminating sand. Their economy, on the whole, is doubtful. Direct metal for steelworks is also mentioned, but pig-beds are still required for Sunday iron. The pig-breaker at the Dowlais Cardiff works is described, together with the overhead cranes for handling the combs of pigs. Reference is also made to the rock-drill for tapping, and the "gun" or appliance for pneumatically forcing clay into the taphole. Continuous casting machines have received attention, and Uehling's apparatus has been successfully used at the Lucy furnaces, Pittsburgh. This consists of two endless chains running on sprocket wheels centred 90 feet apart, at a speed of 15 feet per minute. To the links of the chains overlapping iron moulds are bolted. Two machines are worked side by side, and are fed from a T-shaped trough, which is tilted to direct the metal to one side or the other. The pigs are sprinkled with water, and are solid at the end of the chain, or in six minutes. The moulds are made of soft grey iron 22 by 12 by 7 inches, and are $\frac{3}{4}$ -inch thick; they last forty-five days, and a double machine handles a ton of metal per minute. The red-hot solid pigs drop on to a conveyor, which carries them through water and then drops them into railway trucks. It is suggested that the metal should first be run through a mixer to secure uniformity.

The methods for dealing with blast-furnace slag are nearly perfect. The Weimar cinder-car consists of a ladle mounted on trunnions on two four-wheeled bogies, and lined with firebrick or cast iron staves. The Howdon slag-conveyor successfully handles slag intended for road metal, and illustrations are given of one 100 feet long at two furnaces of the Cambria Iron Company. Granulating slag and slag wool are mentioned.

A plan of Uehling's appliance for casting pig iron into a travelling belt of moulds has also been published elsewhere,* and its advantages enumerated.

* *American Manufacturer*, vol. 1x. pp. 583-584.

Professor W. C. Roberts-Austen brought before the Engineering Congress of the Institution of Civil Engineers the subject of the mechanical appliances for handling materials which are charged into or issue from furnaces.

Rapid Furnace-Building.—The Rosena furnace at New Castle, Pennsylvania, was destroyed by a slip and explosion on May 23, 1896, but the four stoves were not injured. The furnace was rebuilt and ready for blowing in by the second week of September following. Photographic illustrations showing the progress of construction have appeared,* with some details of the work. Delay was caused at first by the removal of the old furnace and the salamander which was blasted. The height of the stack has been increased from 75 to 100 feet and the boshes from 18 to 20 feet. The hearth is 13 feet in diameter. There are sixteen $4\frac{1}{2}$ -inch tuyeres. Bosh-plates are made of copper instead of bronze. The bustle-pipe is constructed with special reference to the use of fine ores, and there are provided two explosion doors, consisting of inverted counterbalanced bells placed on upward extensions of the downcomers, which are 6 feet in diameter. The casing is built of steel plates of unusual size, four forming each ring; their thickness ranges from $\frac{3}{4}$ to $\frac{1}{2}$ inch.

Blast-Furnace Gas.—H. Hubert † discusses the direct utilisation of blast-furnace gas for the production of motive-power. Blast-furnace gas has been employed in this way at the works of the Cockerill Company with considerable success.

Blowing Machinery.—Illustrations are published of the Ehrhardt-and-Sehmer type of horizontal blast-furnace blowing-engine. This engine is constructed for a maximum boiler-pressure of eight atmospheres, and a maximum blast-pressure of 0·5 atmosphere. Details are given as to its dimensions and method of construction. It is pointed out that the blast-furnace plants of the Saar, in Luxemburg and in Lorraine, usually employ only very low pressure of blast, and that for these this form of blowing-engine is very suitable. Two such are now employed at the Burbach Ironworks.‡

O. Vogel § quotes from the journal of Baron von Dalem, who visited

* *Iron Trade Review*, vol. xxx. No. 36, pp. 9-10, with illustrations.

† *Annales des Mines de Belgique*, vol. ii. pp. 233-268.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. pp. 884-885, four illustrations.

§ *Stahl und Eisen*, vol. xvii. p. 745.

the United Kingdom in the years 1774 and 1786. He describes the Carron Ironworks, and referring to the latter year observes, with regard to the blowing appliances, that the bellows had recently been replaced by "a kind of air-pump," set in motion by a large water-wheel. Two pumps were always rising while two were going down, and a pipe conveyed the blast produced to the furnace. The works at that time employed about 500 men. Cast iron was chiefly produced, wrought iron being only made in relatively small quantities. In 1786 the works was chiefly engaged in casting iron water-pipes for the city of Edinburgh. Cannon was also made, pieces up to the size of 24-pounders being cast at this works. In four blast-furnaces "half-burnt coal, lime, good English iron ore, and poor quality ironstone found in the neighbourhood" were smelted. In the twenty-four hours the furnaces were tapped twice. The Baron's journal is not merely interesting in itself, but as showing about the date at which the new form of blowing-engine was introduced at the Carron works, a date which has hitherto been considerably in dispute, Beck fixing the year 1768 and others 1775, while yet earlier dates have been proposed.

Cooling Plates for Blast-Furnace Boshes.—Illustrations are published* of an arrangement of the pipes for supplying water to the cooling plates built into the boshes of blast-furnaces. A number of annular pipes are placed round the furnace between each two rows of plates, to which they are connected by short lengths of smaller pipes. The annular pipes are fed from a main outside the columns. By the arrangement described the plates are rendered more accessible.

Blast-Furnace Tops.—Amongst the designs for obviating the effect of explosions in blast-furnaces, one of those by F. H. Foote has been illustrated.† In this, instead of using flap explosion-doors, the charging cone rests in a seal on the top of the furnace; but in case of explosion the bell and cone rise vertically, leaving a free annular space for the escape of gas. Vertical guides control its movement.

Blast-Furnaces in the United Kingdom.—O. Simmersbach ‡ publishes a series of sketch sections of blast-furnaces as used in the United Kingdom since 1828, derived from various sources. He refers

* *Iron Age*, vol. ix. No. 4, pp. 14, 15.

† *Iron Trade Review*, vol. xxx. No. 25, and No. 38, p. 8.

‡ *Stahl und Eisen*, vol. xvii. pp. 309-313; fourteen illustrations.

generally to the progress that has been made in blast-furnace practice in the United Kingdom since that date, and to the utilisation and treatment of the blast-furnace gases.

An Ancient Welsh Blast-Furnace.—An old blast-furnace known as Y Gwaith Haiarn stands on the left bank of the river Agmore, about a mile from Bridgend, on the windward side of a hill. It is 12 feet high, $6\frac{1}{2}$ feet square at the base, and 3 feet square at the top. Only a section of one-third remains, according to Mrs. Spencer.* The same furnace is also described by W. Morgan,† who shows that clay-band must have been the ore used, with limestone as flux.

Blast-Furnaces in Scotland.—According to a letter which recently appeared in the *Glasgow Herald*, the oldest Scotch ironworks proper dates from 1754. In that year the Argyll Furnace Company founded the Lorn Furnaces on Loch Etiveside. The Argyll Furnace Company was an English copartnery, bringing down English ore to be smelted with Scotch wood, and taking the iron back with them. Their successors, Harrison, Ainslie & Company, carried out a similar practice, the furnaces only being blown out a few years ago on the exhaustion of the oak woods. The oldest ironworks in Scotland is the Carron works, founded in 1760 by Roebuck, Cadell & Company. Carron works, planned with the help of Smeaton and of Watt, became the most famous ironworks of its day. From the first the company smelted iron, partly from Scottish, partly from English ores, but they sold none of their pigs. They kept the whole to feed their foundry, and for their bar ironworks, and their Cramond slit mill. Between Carron and Cramond they made pretty nearly all sorts of iron ware—heavy castings, such as cylinders and engine seats, “carronades” and other guns; light castings, such as grates and stoves, pots and pans; wrought iron, such as spades and hoes, hinges and hoops, bolts and nails.

Between the years 1780 and 1790 four new ironworks were founded—Wilsontown, Omoa, Muirkirk, and Clyde. Clyde, the oldest ironworks in this district, dates from 1786, when Thomas Edington (father of the founder of the Phoenix Foundry) acquired the site from James Dunlop of Tolcross, on behalf of himself and William Cadell of Barnton, and the other partners of the Clyde Iron Company. The Clyde Iron Company was a distinct copartnery, but Edington and

* *The Antiquary*, vol. xxxiii. p. 260.

† *Western Mail*, through *ibid*.

Cadell were leading partners in the Carron Company, and the Clyde works were meant as a feeder to Carron and Cramond. The iron that the Carron Company had been importing from Russia and Sweden had risen on their hand till for bars they were paying £24 a ton, and Clyde, standing on coal and close to ironstone, was expected to relieve Carron from its dependence on the Muscovite and the Swede. But Clyde, like Carron, had its air-furnaces, its cupolas, and rolling-mills, and these soon came to consume, for miscellaneous wares, more pigs than its blast-furnaces made, and Clyde, instead of having anything to spare for Carron, had itself to import from Wales. In 1810 the Clyde works were bought by Colin Dunlop of Tolcross, and in Dunlop's hands the miscellaneous by-products were long given up, and nothing produced except pigs. Of course long before this era there were "works" which followed the primitive smelting of bog-iron with charcoal, the evidences of whose existence are to be found on many Scotch moors in the heaps of slag remaining from the production of blooms.*

The *Shipping World* † publishes an illustrated description of the Carron works. The works were founded with the modest capital of £12,000 by Dr. John Roebuck in 1759, the first blast-furnace being blown in on Christmas Day 1760. The article contains photographic views of the exterior of the works, the blast-furnaces, the loading bank, the heavy foundry, the old north gate, and the old offices.

The Kraft Blast-Furnaces.—A description is published of the new Kraft ‡ ironworks in the Kratzwick district, on the left bank of the Oder. There are two large blast-furnaces, detailed plans and elevations of which are given. Each is provided with six tuyeres and two slag tuyeres. A Lange bell with central take-off is employed. For the purpose of cleaning the gas, a rectangular iron box-like erection is used. It is nearly 60 feet high, $21\frac{1}{2}$ feet broad, and 41 feet long. It is partitioned off into six chambers, in and out of which the gas is made to go as it passes from the furnace. The dust settles out into a water-tank, from which it can be readily removed. Cowper stoves are employed. These are also illustrated. There are eight of these, each 77 feet high and $21\frac{1}{4}$ feet in diameter. Considerable use is made at the works of the electric transmission of power. A number of interesting details are given, and the works is further of interest in that, owing to the nature of the ground on which it was

* *Industries and Iron*, vol. xxii. p. 508.

† Vol. xvii. pp. 425-428.

‡ *Stahl und Eisen*, vol. xvii. pp. 705-708, with plates and illustrations.

built, ten thousand piles, consisting of large tree-trunks 39 to 46 feet long, had first to be driven in for the purpose of obtaining an adequately secure foundation. The ground was marshy, and subjected to periodical flooding by the adjacent river.

Russian Ironworks.—A translation by G. Kamensky * of a lengthy paper by Professor Thimé on the South Russian iron industry has been published.

Canadian Blast-Furnaces.—A general review of the iron and steel industry in Canada has been published.† After mentioning the ores found, a historical sketch of the various furnaces, dating back to 1837, is given. A historical review of the legislation bearing on those metals follows, after which some statistics are appended. The various companies are then dealt with in some detail. The Nova Scotia Steel Company possesses a blast-furnace at Ferrona 65 feet high, with bosh diameter 15 feet, and three Massick & Crookes stoves $16\frac{1}{2}$ by 60 feet. This works also owns coal-washing plant, fifty-two Bernard ovens, an ore-washing plant, and two 20-ton Siemens steel furnaces and one 35-ton furnace, together with rolling-mills. The Pictou Charcoal Iron Company has a furnace 50 feet high, with boshes 11 feet in diameter. Blast is heated in an iron-pipe stove. Charcoal is made in six beehive ovens and sixteen Plattsburg conical ovens. The Canada Iron Furnace Company chiefly treats lake ore at Radnor Forges in a furnace which is 40 feet high, with 8-foot boshes. The Hamilton Blast-Furnace Company started its furnace in February 1896, and in that year made 25,270 tons, with a consumption of 30,217 tons of coke, 8469 tons of flux, and 43,900 tons of ore. Some of the dimensions of the furnace are given.

The Illinois Steel Company's Blast-Furnaces.—An illustrated description has recently appeared ‡ of the North and South Chicago works, the Milwaukee works, the Joliet works, and the Union works, Chicago, which are now combined in the Illinois Steel Company. These works comprise seventeen blast-furnaces, four Bessemer steel plants, a very large open-hearth steelworks, two modern rail mills, billet mills, twin-rod mill, plate mill, and merchant mill. At the South Chicago works there are four furnaces 75 feet high and $17\frac{1}{2}$ to $19\frac{1}{2}$ feet

* *Colliery Guardian*, vol. lxxiv. pp. 693, 741.

† *The Canadian Mining Iron and Steel Manual*, 1897, pp. 58-111.

‡ *Iron Age*, vol. lx. No. 3, pp. 6-12; *Iron Trade Review*, vol. xxx. No. 28, pp. 11-24.

in the boshes, each with four Whitwell-Foote stoves 21 by 67 feet, and also four furnaces 85 feet high and $19\frac{1}{2}$ to $20\frac{3}{4}$ in the boshes, each with four Massick & Crookes stoves, 22 by 74 feet. Adjoining these latter furnaces is a plant in which the flue-dust is made into bricks, which are charged back into the furnaces. The first furnace makes spiegeleisen, usually 7000 tons monthly. The Bessemer plant includes two revolving 150-ton mixers, three cupolas 10 to 11 feet in diameter, and three 12-ton converters with special bottom-changing appliances. An intermediate receiving-ladle was installed in 1893 for improving the mixing with the recarburiser. The open-hearth plant contains four 25 to 28-ton furnaces of the Wellman stationary type, two 25 and four 60-ton furnaces of his revolving type. A casting-pit 30 feet deep allows ingots up to 150 tons to be cast. The Union works possesses two furnaces 75 feet high and $15\frac{1}{2}$ feet in the boshes, with five hot-blast stoves. At one furnace the metal is run into moulds 20 feet long, and the casting is taken by an electric crane and roller-table to a breaker. There are two converters. The North Chicago works has two 65 by 16 feet blast-furnaces and two 6-ton converters. A cement plant for utilising slag is attached to these works. The Milwaukee works has two blast-furnaces 16 by 66 feet, each with three 18 by 60 feet Massick & Crookes stoves. The Joliet works has three blast-furnaces ranging from 78 to 81 feet in height and $19\frac{1}{2}$ to 20 feet in the boshes, each with four stoves of different types. There are two 10-ton converters. Besides the other mill plant, there are two Garrett rod-mills. The rolling-mills at each of the works are also described.

Blast-Furnaces in Alabama.—In some notes on the Birmingham district, Alabama, J. S. Kennedy* gives the number of blast-furnaces in the State as thirty-nine, of which twenty-six are in the Birmingham district. Of the latter, twenty are active. Thirteen furnaces are owned by one company. The most important plant is at Ensley, where the first furnace was blown-in in 1889. It now consists of four furnaces 80 feet in height, with boshes $19\frac{1}{2}$ and hearths 12 feet in diameter. There are sixteen 65 by $20\frac{1}{2}$ feet Gordon three-pass stoves, which are used with three of the furnaces, the fourth being now held in reserve. With ore containing 36 per cent. of iron, as much as 303 tons have been made in one day from one furnace. At Bessemer there are four 75 by 17 feet furnaces and one 60 by 12 feet. The latter has made 100 tons daily on brown ores and Blue Creek coke, which is made from unwashed

* *Iron Age*, vol. lx. No. 2, pp. 2-4.

coal, and contains 15 to 16 per cent. of ash. The Alice plant has two furnaces 74 feet high, with $17\frac{1}{2}$ feet boshes and 11 feet hearth. One furnace only is blown, and five stoves and five blowing-engines are all used in connection with it. The furnace has sixteen 6-inch bronze tuyeres. Coke with 10 per cent. ash made of washed coal from the Pratt seam is used, and 160 to 170 tons daily of low silicon iron with 0.65 per cent. of phosphorus is made. At Thomas there are two blast-furnaces 75 feet in height, with diameter at boshes 17 feet, hearths $10\frac{1}{2}$ feet, bells 9 feet, and stock-line 14 feet. The plant has eight Hartman-Cowper stoves 70 by 18 feet, and a special system for handling the charges. This consists of an inclined hoist, up which the drop-bottom trucks are lifted by a pusher-truck running on a narrow-gauge line between the main rails. This plant is dealt with more fully by Sahlin in another abstract in this volume. Near Bessemer is the Woodward plant, consisting of two furnaces 75 by 17 feet, with $11\frac{1}{2}$ feet hearths. Each furnace has four Whitwell stoves. All the raw material is drawn from points lying within a radius of six miles. Coloured labour is used except in the posts of furnace foremen, stovemen, machinists, and engineers, and the wages paid are 20 per cent. less than five years ago. Other commercial details are also given.

W. B. Phillips * discusses the manufacture of basic iron in the Birmingham district of Alabama. As far as can be seen, ores will have to be used from which iron can be made containing 0.3 to 0.8 per cent. of phosphorus. Generally the percentage will range between 0.7 and 0.85, with a maximum silicon of 1.0 per cent. and of sulphur of 0.05 per cent. This iron is suitable for use in the basic open-hearth furnace, and it is found that it is possible to keep the silicon low by properly running the furnace, so that no further desiliconising process is necessary. Basic iron of this character to the extent of 75,000 tons has been made, and the average analysis of 1188 casts was as follows:—

Si.	S.	P.	Mn.	Graphite.	Combined Carbon.
0.51	0.032	0.72	0.5	2.75 to 3.0	0.6 to 0.8

The ores used were of three kinds,†—I. red fossiliferous Clinton hæmatites; II. soft or lime-free ores; and III. brown ore or limonite, of which analyses were as follows:—

* *The Mineral Industry*, vol. v. pp. 353-370.

† See *Journal of the Iron and Steel Institute*, 1897, No. I. p. 340.

	I.	II.	III.
	Per Cent.	Per Cent.	Per Cent.
Water.	0.50	7.00	13.00
Metallic iron	37.00	47.24	48.54
Silica	13.44	17.20	11.22
Lime	16.20	1.12	0.84
Alumina	3.18	3.35	3.61
Phosphorus	0.37	0.30	0.38
Sulphur	0.07	0.06	0.09
Carbonic anhydride	12.24	...	...

The flux recently employed has been dolomite containing :—

Silica.	Oxide of Iron and Alumina.	Calcium Carbonate.	Magnesium Carbonate.
1.50	1.00	54.00	43.00

The local limestone contained more silicon, and was more variable in composition, and dolomite is used with advantage.

The fuel used assayed as follows :—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
0.75	0.75	89.00	9.50	1.00

The ash of the coke shows :—

Silica.	Iron Oxide.	Alumina.	Lime.	Magnesia.	Sulphur.
45.10	12.32	31.60	1.50	trace	0.10

The particulars of a number of charges are enumerated, covering 195 days, in which 14,309 charges were used, and 30,222 tons of pig iron made. Below a selection is given :—

Percentage of Ore Burden.			Consumption in Tons per Ton of Iron.			Silicon.	Sulphur.	Phosphorus.
Hard.	Soft.	Brown.	Ore.	Flux.	Coke.			
64.0	36.0	...	2.34	0.66	1.52	0.58-0.69	0.035-0.044	0.73-0.74
81.2	18.8	...	2.64	0.12	1.55	0.74-0.95	0.042-0.056	0.69-0.72
64.6	26.5	8.9	2.31	0.68	1.24	0.52-0.63	0.023-0.034	0.76
36.2	53.2	10.6	2.25	1.08	1.32	0.48-0.52	0.028-0.029	0.72-0.73
60.0	20.0	20.0	2.09	0.42	1.05	0.48-0.55	0.039-0.043	0.72-0.75
36.7	42.2	21.1	2.13	1.00	1.22	0.41-0.55	0.021-0.037	0.68-0.71

In specifying for basic iron, only the silicon, sulphur, and phosphorus are considered. The latter is not to exceed 1 per cent., but may readily be kept to 0.75, and is more easily regulated than the sulphur.

When silicon falls, sulphur is apt to increase, but this does not become serious until the silicon is below 0.3. The furnace is then working cold, so the heat must be increased, and the basicity of the slag decreased. When silicon falls below 0.2 the sulphur rises rapidly, but observation of the flow of slag and iron indicates this state of affairs, though the limit can only be decided by the chemist. The burden given second in the list above shows the greatest tendency to increase of silicon and of sulphur, so the burden was changed. In this charge the iron was washed with the equivalent of 89 lbs. of lime per ton, this amount being the equivalent of the bases left after satisfying the silica in the charge in the ratio of 1 of silica to 1 of lime. The last charge mentioned above gave iron of good quality, and calculating in a similar way, there was an excess of 694 lbs. of lime for washing the ton of iron. Other charges are similarly considered, and it is shown that the increase in the basicity of the slag is beneficial, and further that the use of brown ore is of decided advantage, irrespective of the excess of lime. The slag must be basic enough to act on the iron which has been made with less than 0.2 silicon and 0.04 sulphur, by using a surplus of 700 lbs. of lime. Magnesia and lime are depended on as desulphurisers, as manganese in the ore seldom exceeds 0.3 per cent. If this element could be readily obtained, the slags need not be made so basic, but the nature of the local ores render this impossible. In the calculations one part of magnesia is regarded as equivalent to 1.13 of lime, and the alumina is not considered. The author then deals with economy in the consumption of coke, taking for the purpose two examples in which the amounts of materials used, expressed as percentages of the total burden, were as follows:—

	Hard Ore.	Soft Ore.	Brown Ore.	Dolomite.	Coke.
I. . .	35.1	11.7	11.7	11.9	29.6
II. . .	31.5	17.6	2.4	15.1	33.4

The analyses of the raw materials were practically the same in both cases, and do not differ greatly from those given above. In the first case the amount of acid and basic material in the charge is practically the same, and in the second case there is an excess of 376 lbs. of lime per charge, or 197 lbs. per ton of iron made. The first required only 1.09 ton of coke per ton of iron, whilst 1.53 ton was used in the second example. In both instances the quality of iron was good, but there was a somewhat lower yield of the best iron in the latter. The saving is due to the increased use of brown ore. The results obtained show that the production of basic iron has passed the experimental stage.

Pig Iron in the Southern United States.—C. Haller * points out that while in 1872 the total out-turn of pig iron in the Southern United States was only 11,000 tons, mostly charcoal iron, in 1896 no less than 1,833,235 tons was made, 922,175 tons being produced in Alabama alone. The pig iron made is too high in phosphorus for use in the Bessemer process, and until lately only foundry pig iron was made. Now, however, Southern pig iron is largely used in the basic open-hearth. The largest blast-furnace in Alabama is 80 feet high and 20 feet in diameter at the boshes. So far the maximum day's out-turn of any furnace has been 265 tons. The average out-turn is, however, but 200 tons, or 180 tons for somewhat smaller furnaces. The ores smelted are of constantly varying composition, and the coke, too, is of poorer quality than it will be as the appliances used are improved. The blast-furnaces, too, are not of quite the best modern standard as to size, pressure of blast, labour-saving appliances, &c. The author estimates the cost of production of the ton of pig iron at from 2 to 2½ dollars, one-half of which is labour charges. He further gives the following table:—

Charge of a Blast-Furnace for each Ton of Iron Made.	Works No. I. Charged.			Works No. II. Charged.		
	Per Cent.	Tons.	Cost, Dollars.	Per Cent.	Tons.	Cost, Dollars.
Hard hæmatite . . .	27.7	1.21	0.81	22.9	1.00	0.68
Soft hæmatite . . .	26.2	1.15	0.66	27.0	1.19	0.68
Brown hæmatite . . .	...	...	...	1.9	0.09	0.08
Totals . . .	53.9	2.36	1.47	51.8	2.28	1.44
Flux . . .	15.7	0.69	0.43	17.1	0.74	0.46
Coke . . .	30.4	1.33	2.05	32.1	1.37	2.11
Totals . . .	100.0	4.38	3.95	101.0†	4.39	4.01

Adding 2 to 2½ dollars general costs to this, the total cost of production of the ton of foundry pig iron amounts to from 6 to 6½ dollars.

Six dollars may be considered to be the lowest price at which the ton of foundry pig iron can now be produced at Birmingham, but this leaves no profit. The average contents of phosphorus in Alabama pig iron is 0.4 to 0.8 per cent. The pig iron made in the Southern States for use in the open-hearth process at Pittsburgh contains on the average 0.42 per cent. of silicon, 0.71 of phosphorus, and 0.026 per cent. of

* *Stahl und Eisen*, vol. xvii. pp. 442-443.
1897.—ii.

† 100.0 in original.
2 C

sulphur, the contents of these constituents falling far below the originally permitted maxima of 1 per cent. each for silicon and phosphorus, and 0.05 for sulphur. A large open-hearth steel plant is now in course of erection at Birmingham, Alabama. Ten tipping furnaces, each taking charges of from 78 to 80 tons, are to be erected. These are to be charged mechanically. They are to work with large percentages of pig iron, and are to produce daily from 1400 to 1600 tons of ingots, which are to be rolled to bar iron, rails, sheets, &c. It is intended that the rail-mill shall have an out-turn of 1200 tons of finished rails in twenty-four hours. A Garrett wire-mill is also to be erected, having an out-turn of from 270 to 300 tons of 0.2 inch round iron in twenty-four hours.

Seven pipe-foundries have been established in Alabama. These have a total daily capacity of 725 tons. They are well arranged and equipped. The author thinks, taking everything into consideration, that the iron trade of Europe has to fear considerable commercial rivalry from the growing iron industry of the Southern United States.

W. M. Brewer* gives a brief history of coal and iron in Alabama as a preface to a series of articles on the subject. There are four companies working iron in the Birmingham district, and charcoal furnaces have been at work at several places in the State, but are mostly shut down owing to the limited demand for that kind of iron. The coal industry is represented by about eighty companies within a hundred miles of Birmingham, working two hundred openings and producing 400,000 tons annually. Twenty-five years ago there were only two mines being worked. The manufacture of coke and bricks is also referred to.

The same author also † gives a few notes on the iron and coal industry of the Southern States generally.

T. G. Bush ‡ also remarks on the development of the iron industry in Alabama, which now ranks fourth in the iron-producing States of America. Birmingham is the centre of the red ore district, and Anniston of the brown ore district.

W. B. Phillips§ also offers some remarks on the composition of Southern pig iron in relation to the export trade.

* *American Manufacturer*, vol. lx. p. 909; vol. lxi. pp. 188, 259, 296, &c.

† *The Mineral Industry*, 1896, pp. 350-351.

‡ Lecture before the Commercial Club of St. Louis, through the *Iron Trade Review*, n. xxx. No. 32, p. 15.

§ *Iron Trade Review*, vol. xxx. No. 35, p. 13.

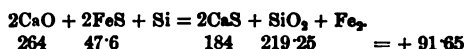
II.—CHEMICAL COMPOSITION OF PIG IRON.

Sulphur in Pig Iron.—In dealing with the occurrence of sulphur in iron, its introduction and removal, E. L. Rhead * upholds the idea that it occurs as sulphide, partly because it is evolved as sulphuretted hydrogen on solution in acid, and partly because the thermal equation of manganese on sulphide of iron has a positive value. Its behaviour during puddling also substantiates this view. The sulphide may be formed by direct combination of iron and sulphur, by the action of sulphur vapour on oxide of iron, by the decomposition of sulphides by iron, and by reactions between metallic sulphides and oxide of iron. Iron does not reduce potassium and sodium sulphides, but some experiments are quoted to show that there is a reaction with sulphides of calcium and magnesium, so that they may be reduced under certain conditions of work. The reaction $\text{CaS} + \text{FeO} = \text{CaO} + \text{FeS}$ has a small negative thermal value, but it may sometimes occur. The high specific gravity and fusibility of sulphide of iron causes its concentration in the iron, and it is not oxidised by oxide of iron.

The various processes for eliminating sulphur or preventing its introduction are then reviewed. In the Massenez process the equation $\text{FeS} + \text{Mn} = \text{MnS} + \text{Fe}$ is exothermic, and is readily possible, and is most effective on direct furnace metal. Soda compounds have been used. With sodium carbonate the reaction is strongly exothermic, and the violent agitation produced ensures the best conditions for success. Sodium nitrate is used in the Heaton process, but does not remove sulphur. Fluor spar, calcium chloride mixed with sodium chloride, and also other substances have been used, but have given irregular results. Saniter's process, in which lime and chloride of calcium are employed, has given successful results with direct and open-hearth metal. The best results occur with metal high, or fairly high, in silicon, and the greatest sulphur removal is coincident with the more complete removal of that element, or, in its absence, of phosphorus. A high temperature is favourable, and in furnace treatment success is greatest when the reagent is introduced early. Sulphur is not removed from molten iron by oxidation, but by heating with basic iron slags. The production of grey siliceous iron with slags containing excess of lime favours low sulphur, and this entails a higher temperature. In keeping down silicon in sulphur-free iron, liquid slags are necessary. There is evidence of the actual reduction of calcium in

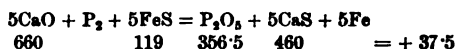
* *Journal of the West of Scotland Iron and Steel Institute*, vol. iv. pp. 102-114.

the furnace, and this metal expels the sulphur from combination with iron. The reduction of lime by carbon demands an enormous absorption of heat, but much less is required for its reduction by silicon, and the following exothermic equation may be considered :—



and some evidence based upon remarks by Snelus and Stead is given to support the possibility of this reaction. It is noted that the addition of lime to keep down silicon does not necessarily mean that silicon is not reduced.

In the basic process sulphur is chiefly removed during the after-blow, and the author ascribes much of the action to the phosphorus :—



This occurs during the after-blow when the lime is in solution.

The author concludes that, if his deductions are correct, it should be possible to desulphurise phosphoric metal after decarburisation, as actually happens in the basic Bessemer process, and it may become profitable to blow in an acid converter and finish in a basic furnace with the Saniter additions, the larger amount of phosphorus remaining in the acid-blown metal effecting an even greater elimination of sulphur than actually takes place at present.

Pig Iron from the Ougrée Steelworks.—These works are in the neighbourhood of Liège.* The following are analyses of the ore smelted :—

No.	Loss.	SiO ₂ .	Al ₂ O ₃ .	CaO.	MgO.	Mn ₂ O ₃ .	Fe ₂ O ₃ .	P.
	P. Cent.	P. Cent.	P. Cent.	P. Cent.	P. Cent.	P. Cent.	P. Cent.	P. Cent.
1.	18·50	6·30	8·90	8·00	0·40	0·32	56·60	0·72
2.	13·80	19·20	8·00	2·70	0·30	0·37	54·50	0·61
3.	6·92	15·00	10·00	2·50	1·30	0·10	61·96	0·56
4.	14·10	9·70	8·84	0·50	traces	27·57	38·42	0·12
5.	15·00	5·16	1·39	2·00	traces	22·93	49·13	0·21
6.	9·50	6·90	3·40	2·50	0·70	1·00	75·70	0·03
7.	6·78	7·10	1·82	0·30	traces	1·25	31·36	0·03
8.	1·34	11·30	2·71	2·00	1·50	12·77	67·38	0·05
9.	1·50	11·00	1·00	1·00	0·40	traces	82·74	0·06
10.	43·30	0·70	0·20	54·00	0·50	traces	0·30	0·01

In addition No. 3 contains 0·05 per cent. of sulphur, No. 8, 0·434 per cent., and No. 9, 1·15 per cent. The rest contain no sulphur, or only traces.

(1) Oolitic iron ore from Luxemburg; (2) Oolitic ore from Belgium; (3) Iron glance from Namur; (4) Brown iron ore from Germany; (5) Brown iron ore from Greece; (6) and (7) Red hematites from Spain; (8) Calcined spathic ore, Germany; (9) Blue billy; (10) Limestone used as flux.

* *Stahl und Eisen*, vol. xvii. pp. 816-817,

The slags approach a monosilicate in character. The following are analyses of the metals made:—

No.	Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1.	4.500	2.463	2.042	0.014	0.060
2.	4.500	2.845	0.90 to 0.40	0.010	0.048
3.	4.325	0.807	1.820	0.054	2.344
4.	3.987	1.307	0.407	0.056	0.117
5.	4.400	0.409	0.131	0.329	1.528
6.	5.800	0.503	7.232	...	0.892
7.	5.100	1.127	4.213	traces	0.223
8.	4.000	1.121	2.988	traces	0.093

(1) Bessemer pig iron for rails; (2) "Extra" Bessemer metal for tires, axles, springs; (3) Basic pig iron for rails, wire, sheets, &c.; (4) Foundry iron for rolls, machine parts, &c.; (5) Forge pig iron Nos. 2 and 3, for boiler and other plates; (6) Spiegeleisen for tires, fine sheets, &c.; (7) Bessemer spiegel for pipe sheets; (8) Mottled Bessemer pig iron for certain kinds of sheets.

The slags produced in making these had the following percentage compositions:—

No.	SiO ₂ .	Al ₂ O ₃ .	CaO.	MgO.	MnO.	FeO.	S.	P.
	P. Cent.	P. Cent.	P. Cent.	P. Cent.	P. Cent.	P. Cent.	P. Cent.	P. Cent.
1.	32.210	11.370	50.420	1.370	0.850	0.760	2.726	0.008
2.	30.000	12.340	51.000	2.340	0.300	1.050	2.726	0.022
3.	32.970	12.440	47.950	1.370	2.260	1.470	1.424	0.078
4.	35.500	8.720	46.500	3.200	1.580	1.160	1.644	0.017
5.	34.350	14.660	42.660	2.000	0.920	3.300	1.422	0.135
6.	32.250	11.170	46.200	2.016	5.070	0.600	2.521	0.019
7.	33.100	10.330	49.700	1.340	2.040	0.670	2.695	0.025
8.	34.000	9.786	47.000	3.300	2.325	0.650	1.800	0.013

This works used formerly to smelt the so-called Ourthe ores, zinciferous brown iron ores from the Devonian and Carboniferous limestone, but these have long since been worked out. In addition to the blast-furnace plant, the works is provided with an important steel plant, and is now about to start in full work a branch works near Taganrog, in Southern Russia.

Basic Pig Iron.—J. Smeysters* reports that the third blast-furnace of the Providence Works in Belgium began making pig iron on July 9. In order to give the pig iron the requisite proportion of man-

* *Annales des Mines de Belgique*, vol. ii. pp. 715-716.

ganese, ore from Bayonne is added, its percentage composition being as follows :—

Silica	6 to 8
Iron	5 to 6
Calcium carbonate	14 to 15
Alumina	1 to 2
Phosphoric acid	0·1 to 0·2
Manganese	27 to 30

Ore from Huelva, with 14 to 18 per cent. of silica and 34 to 42 per cent. of manganese, is also used.

Pig Iron from the Longwy Steelworks.—The Longwy Steelworks are situated near Arlon, and not far from the Belgian-Luxemburg border.* They possess altogether seven blast-furnaces, and smelt almost exclusively the oolitic ores of the adjacent district. Some Bilbao ore is used for a special brand of pig iron. The following are partial analyses of the local ores :—

	Hussigny.	Mont St. Martin.	Godbrange.	Herserange.	Moulaine.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Iron	39·70	41·30	40·60	41·90	37·90
Manganese	0·20	0·25	0·15	0·15	0·15
Silica	11·95	17·83	12·59	10·95	13·60
Lime	7·47	3·34	5·33	5·05	8·05
Alumina	7·86	7·10	8·32	7·95	7·52
Sulphur	0·20	n. d.	n. d.	0·30	n. d.
Phosphorus	0·70	0·60	0·60	0·70	n. d.

n. d. = not determined.

The following are analyses of calciferous ores used in the charge for fluxing purposes :—

	Herserange.	Moulaine.	Hussigny.	Godbrange.	Saulnes.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Iron	27·20	23·58	27·80	30·90	30·04
Manganese	0·15	...	0·15	0·35	0·15
Silica	11·85	9·90	9·36	10·60	11·25
Lime	19·25	23·66	19·08	16·84	16·82
Alumina	7·10	6·56	7·61	7·21	7·27
Sulphur	0·25	n. d.	0·25	n. d.	n. d.
Phosphorus	0·50	n. d.	0·50	n. d.	n. d.

n. d. = not determined.

* *Stahl und Eisen*, vol. xvii. pp. 817-818.

In addition to these calciferous ores, limestone of the following percentage composition is also in use for fluxing purposes :—

Silica.	Alumina.	Ferric Oxide.	Lime.
3.3 to 3.5	0.91	1.70	51.5 to 52.3

An improved form of Cowper stove is used at the blast-furnace works. The blast-furnaces themselves have produced 153,000 tons of basic pig iron from 529,000 tons of ore and fluxes. The following are analyses of the pig iron made :—

	Mn.	C.	Si.	S.	P.
Soft basic pig iron . .	1.5	3.0	0.20 to 0.3	0.04 to 0.06	2.0
Mottled basic pig iron .	2.0	3.2	0.35 to 0.6	0.02 to 0.05	2.0

These are apparently averages.

Four kinds of pig iron are made for foundry use. They contain—

No.	Silicon.	Graphite.
	Per Cent.	Per Cent.
1.	2.7	3.20
2.	2.3	3.05
3.	2.0	3.00
4.	1.4	2.50

together with from 0.02 to 0.09 per cent. of sulphur, and from 0.09 to 0.06 per cent. of phosphorus.

Argentiferous Pig Iron.—A. Ledebur* gives the following analysis of some liquation products from molten spiegeleisen :—

MnO.	FeO.	SiO ₂ .	P ₂ O ₅ .	Mn.	S.	Total.
79.77	5.98	12.81	...	0.81	0.47	99.84

The mother-metal contained 9.65 per cent. of manganese and only a trace of sulphur. A further investigation led to some interesting results. If sulphuretted hydrogen was passed into the hydrochloric acid solution of these liquation products, a dark brown precipitate was formed. This was found to contain neither copper, antimony, nor arsenic, but molybdenum appeared to be present. The presence of silver the author considered quite improbable, but further investigation showed its presence in quantities amounting to 0.03 per cent. of the liquation products. This result was most surprising, partly because

* *Stahl und Eisen*, vol. xvii. pp. 482-483.

it has been customary to assume that silver is quite insoluble in iron, as well as from the fact that the precipitate in which the silver had been found was produced by sulphuretted hydrogen from a hydrochloric acid solution. It is possible that this solubility may have been due to the manganese that was present. The silica that had been left after the solution was examined for silver chloride, but none was present, and it would seem that manganous chloride is a strong solvent for the silver salt. It is probable, too, that it was the presence of manganese that led to the liquation of the silver. To ascertain the percentage of silver contained in the mother-metal, 100 grammes of the iron was dissolved in hydrochloric acid, and, without filtering, sulphuretted hydrogen was passed through. The solution was then filtered and the precipitate washed with sulphuretted hydrogen water to get rid of that portion of the iron and manganese that had passed into solution. The residue was ignited, fused with some nitre and with sodium carbonate, and the silica separated in the ordinary way. In this instance, too, it was perfectly free from silver. From the solution, which still contained a somewhat large quantity of manganese, the silver, copper, antimony, and arsenic were reprecipitated with sulphuretted hydrogen, and the silver so obtained was found to amount to 0.0018 per cent. of the pig iron. That is to say, one metric ton of the pig iron examined contained more than half an ounce of silver, while in the excrescences it had concentrated to the extent of some fifteen times this percentage. The pig iron examined contained some arsenic and antimony, as well as a small percentage of molybdenum. The iron ore from which the pig iron in question was produced, contains very little lead, and none of this metal is collected in the blast-furnace treatment of this ore.

The Valuation of Foundry Pig Iron.—In a paper read before the Verein Deutscher Eisengiessereien, Wüst* observes that pig iron is bought by its external appearance, and the character of its fracture still forms the basis of its grading. The coarsely crystalline dark grey graphitic pig iron is called No. I., and at the time the author read his paper was worth in Germany seven shillings a ton more than the fine-grained and less graphitic No. III., or one-ninth of the total value. The author discusses the question whether this method of classification is an accurate one, and this he answers in the negative. The more strongly the iron had been heated in the blast-furnace and the more slowly it had been cooled down, the coarser is the grain. The result

* *Stahl und Eisen*, vol. xvii. pp. 848-856.

is that the appearance of the fracture is not in any way a safe guide as to the chemical composition of the material, especially as regards the percentage of silicon. It is possible by slow cooling to give the same fracture to a pig iron with adequate carbon, but the percentage of silicon in which is considerably below 2, as is possessed by a pig iron richer in silicon, though its value in the foundry might be nil. The actual value of a pig iron in a foundry is dependent on the quantity of scrap that may be added to it without the casting being hard and brittle. The yield of castings varies greatly in a foundry. In one in which only small hardware castings are made it may be only 55 or 60 per cent. of the pig iron used, while, on the other hand, it may be from 85 to 90 per cent. in a works in which, on the whole, only large castings are produced. As some silicon and graphite is lost with every additional melting, the resulting scrap requires the addition of a metal higher in silicon. In addition, however, to the scrap being used that is produced at the works itself, it is customary to purchase other scrap, which is cheaper than pig iron. It is therefore commercially important to be able to use as much of this scrap as may be at all possible, or, failing such scrap, some cheaper kind of pig iron. According to the appearance of the fracture of the foundry iron the charges are made up, and this fracture may be deceptive. This method of making up the charges is therefore based on false data, and is illogical. The pig iron made in the same blast-furnace and under apparently similar conditions, is not always of the same character. It varies in composition with each successive tapping. If the iron-founder mixes his charge without taking into consideration the changes in the chemical composition of the metal, he may get a casting of doubtful quality on the one hand, or, on the other, he might have been able to have used a larger percentage of scrap without danger to the resulting casting. To prevent this danger, some founders, instead of using one particular brand of a pig iron, use three or four, trusting in this way to maintain a fairly average constant composition. The higher the percentage of silicon in a foundry pig iron, the larger is the percentage of scrap that may be added to it without the casting being rendered brittle. Much more than 4 or 5 per cent. of silicon should not, however, be present in a foundry iron, as with the increase in the percentage of silicon there is a corresponding decrease in the percentage of carbon. There is, therefore, a maximum percentage limit. A high silicon iron like this, containing relatively little graphite, has a fine-grained fracture, and

such a metal may be purchased as No. III., despite the fact that it may be a most valuable foundry iron. The percentage of carbon in cupola-melted metal is not less than three, and even when steel scrap is melted in the cupola the percentage of carbon is still about three—that is to say, pig iron has been produced in the cupola from the steel scrap charged. Three per cent. of carbon is, however, sufficient for the separation of graphite if adequate silicon is present. It is better to have a not too high percentage of carbon, one not above 3.5, if good tough castings are to be produced, rather than to use a pig iron high in carbon, which, especially in thick castings, is apt to yield a casting of poor quality. The percentage of carbon contained in a pig iron used for foundry purposes can therefore be disregarded.

The percentage of manganese in the metal is an important matter influencing the mode of occurrence of the carbon in the iron. It hinders the formation of graphite, and leads to a hard and brittle casting. In the pig iron itself manganese is of advantage, as it prevents loss by oxidation of the silicon when the metal is remelted in the cupola, passing into the slag in its place. Hence when it is a choice between two samples of pig iron with equal silicon contents, that with the more manganese is the better of the two, as it will stand more frequent remeltings in the cupola. Too much manganese must not, of course, be present. The presence of a considerable quantity of manganese in a pig iron is a guarantee that the metal is low in sulphur. By using limestone in the cupola, and coke not too high in sulphur, there is not much danger to the castings on the score of sulphur. The conditions of casting, too, are of great importance on the character of the casting produced. If a pig iron mixture is cast very hot and a similar mixture less heated, the former might under circumstances produce a good casting, while the latter might not give satisfactory results. A pig iron mixture which, for thin castings, might be quite useless, might give very satisfactory results when used for thick castings, the conditions of cooling being different in the two cases. In the former instance the metal must be higher in silicon to counteract the influence exerted on the quality of the metal by the more rapid cooling. On this point, again, it is a matter of importance whether the mould into which the metal is cast is wet or dry. The moisture contained in mould sand varies from 7 to 10 per cent. From 2 cwt. of sand, therefore, the metal would have to evaporate about 20 lbs. of water, and the cooling action on the metal is considerable. Various other points are also considered.

With a view to clear up the various points discussed, the author obtained samples from 120 castings made at twenty-one different foundries in all parts of Germany. These samples he analysed for silicon and manganese, and his results are tabulated in considerable detail, descriptions being given of the kind of casting, its weight, how it was cast, the appearance of its fracture, and its mechanical properties. The percentages of silicon shown varied between the limits 0.42 and 2.62, with one exception. In this case the percentage of silicon was 4.73. The percentages of manganese ranged from 0.46 to 1.38, with the exception of three castings in which the percentages of manganese were respectively 1.91, 1.89, and 2.26. As a rule, the percentage of silicon was round about 2, with manganese under 1. The samples showed the following percentages of silicon:—

Thickness of Side of Casting. Inch.	Percentage of Silicon.
Under 0.39	2.5 to 2.3
0.39 to 0.79	2.1 to 2.3
0.79 to 1.18	1.9 to 2.1
1.18 to 1.58	1.7 to 1.9
1.58 and over	1.5 to 1.7

If the hardening action of manganese on a casting is to be avoided, it ought not to be much in excess of 0.8 per cent. The author shows in an example the percentage composition of the metal that should be employed to produce a casting containing 2.29 per cent. of silicon. The pig iron used, he considers, should not contain more than 1.3 per cent. of manganese, nor less than 0.7. The more phosphorus a pig iron contains, the less valuable is it for foundry use; and taking the then ruling market prices for his basis, the author calculates the approximate price the metal should fetch containing 2.0, 2.1, 2.2, 2.3, 2.4, and so on up to 3.5 per cent. of silicon, and also either under 0.1 per cent. of phosphorus, or 0.3 to 0.8, 0.8 to 1.3, or 1.3 to 1.8. The following are some of these values—

Silicon per Cent.	Phosphorus per Cent.			
	Under 0.1.	0.3 to 0.8.	0.8 to 1.3.	1.3 to 1.8.
	Price, Shillings.	Price, Shillings.	Price, Shillings.	Price, Shillings.
2.0	61.5	59.5	56.5	53.5
2.3	63.0	61.0	58.0	55.0
2.5	64.0	62.0	59.0	56.0
2.8	65.5	63.5	60.5	57.5
3.0	66.5	64.5	61.5	58.5
3.5	69.0	67.0	64.0	61.0

The cost of various mixtures is then calculated, and the author shows that the increasing value of the pig iron, according to its increasing percentage of silicon, is thoroughly justified, and he thinks that the purchase of foundry pig iron according to its silicon contents might also be of advantage to the German blast-furnace manager. Thus in 1896 he shows that some 300,000 tons of foundry iron were imported into Germany from the United Kingdom, and he thinks that were the metal sold by analysis, and not by brand or fracture, German pig iron would replace that imported from the United Kingdom.

Analysis of a Blast-Furnace Product.—L. Franck* has submitted to detailed examination a product observed in repairing the hearth of a blast-furnace in Luxemburg. This he has examined both chemically and microscopically. The quantity of material at his disposal was, however, too small to enable him to make the examination so complete as he would have wished. The material was partly crystalline and in part amorphous, and of an "iron" colour. The fracture showed the presence of titanium compounds. The material could be broken down under the hammer, and this treatment showed both very soft and very hard substances to be present. A qualitative examination in the dry way showed the presence of cyanogen compounds, arsenides and sulphides, phosphorus compounds, carbon, silicon compounds, and others of titanium, iron, and manganese. On treatment with boiling water, some of the material was dissolved, and this was found to contain potassium and sodium ferrocyanide. The insoluble material on treatment with dilute hydrochloric acid evolved strong-smelling gases which contained the hydrogen compounds of sulphur, arsenic, phosphorus, and carbon. The solution showed the presence of iron and manganese. The author describes at length the results of his investigations. Amongst other substances he noted the presence of the following:— Mn_3P_2 and Mn_4P_2 ; carbides of manganese; the carbides of iron, FeC_4 , Fe_3C_2 ; iron phosphides, silica in various forms, iron amianth being chiefly present with amethyst, tridymite, &c.; carbon in various forms, including seven graphites of varying specific gravities; the compound $Ti_{10}C_2N_8$; "alloys" of titanium and carbon, varying in percentages of carbon from 16.84 to 46.83, the percentages of titanium varying respectively from 71.5 to 50.0; some nitrogen and silicon being also present, silicon carbide, and a substance which the author believes to be undoubtedly diamond. Some nitrides were

* *Stahl und Eisen*, vol. xvii. pp. 449-455.

also present, and rutile. In his final conclusions the author observes that the product would appear to have been a sublimation product, which was formed at a very high temperature, and gradually separated under pressure. His investigations, he considers, further show—(1) That crystalline silica may be produced in all forms in the blast-furnace, though the crystals are only of a microscopic character; (2) Carbon is present in “all three modifications” in certain blast-furnace products, graphites being observable, which are hard to distinguish from black diamonds; (4) The graphite in the particular product examined had its origin mainly in cyanogen compounds; (5) Carbon combines with titanium in all possible proportions forming crystallised titanium carbides of similar properties; (6) Cyanonitride of titanium often contains impure diamond, and he thinks that this substance might be used as a solvent for the diamond, and observes that the latter often owes its colorations to the presence of titanium oxides; (6) Silicon combines in all proportions, and all silicon carbides react with polarised light; (7) Diamonds are to be met with, and these may be combination products; and (8) Nitrogen compounds, and chiefly the cyanides, play important parts in inducing the crystallisation of carbon and of the carbides.

III.—BLAST-FURNACE SLAGS.

Slag Cement.—Jørgensen * adds to ordinary slag cement from 5 to 30 per cent. of a material made from slag cement by mixing it with water, partly hardening and then grinding it. The cement so produced is stated to rival Portland cement in character.

A. D. Elbers † discusses nitrosylised blast-furnace slag as an addition to hydraulic cement. It is shown that this form of slag, which is treated with dilute nitric acid to remove the sulphur, may safely be used. A number of tensile and other tests are given.

Blast-Furnace Product.—L. Blum ‡ discovered, during the demolition of a blast-furnace at Esch, in Luxemburg, in the masonry 6 feet above the tuyeres, large quantities of a magnificently crystallised substance, found on analysis to consist of pure oxide of zinc. This

* *Chemiker Zeitung*, vol. xxi. p. 205.

† *Engineering and Mining Journal*, vol. lxiii. p. 661; vol. lxiv. pp. 364, 454.

‡ *Revue Universelle des Mines*, vol. xxxviii. pp. 354-355.

discovery appears to indicate the presence in the oolitic iron ore of Luxemburg of traces of zinc that have not yet been detected by analytical methods.

IV.—FOUNDRY PRACTICE.

Recent Progress in the Foundry.—R. Moldenke* deals with recent progress in the foundry, due to the more rigorous application of scientific methods. Chemistry, for instance, has enabled scrap to be used more freely, and material is more generally bought on analysis. Less coke is used for melting iron, but the ratio cannot be much changed in the cupola for fear of oxidising the iron. Proposals for new cupolas multiply rapidly, showing that much interest is taken in the subject, but more is to be done with the regenerative gas-fired furnace. The improvements in fans, boilers, engines, cranes, and other appliances are briefly referred to, and also the transmission of power, moulding and cleaning machines. The nature of the iron used, and the methods for ensuring the proper quality of the mixtures are then dealt with at greater length, especially from the point of view of the chemist and the irregularity of the scrap, upon the sorting and grading of which so much depends.

Some correspondence on the application of science in the foundry from the above author and others has also appeared † in relation to the bursting of some rolls.

The Behaviour of Silicon in Foundry Practice.—Some data have been collected ‡ of the behaviour of silicon in foundry practice, and the following table shows the percentage of this element in the pig and in the casting, crucible melting being employed :—

Pig iron . .	0·90	1·70	0·55	2·69	0·56	0·68	0·73	2·49	0·30
Casting . .	0·86	1·20	0·48	2·42	0·37	0·62	0·60	2·25	0·10

From these, and a number of similar results, the average reduction of silicon is calculated at 15·36 per cent. Varying opinions on the loss in cupola-melting are held. Thus, J. H. Geer states that in foundry practice it is usual to calculate a loss of 25 per cent. of the silicon from

* Paper read before the Pittsburgh Foundrymen's Association, through the *American Manufacturer*, vol. lx. pp. 621-624.

† *American Manufacturer*, vol. lx. pp. 799 and 836.

‡ *Ibid.*, vol. lxi. p. 332.

pig iron to casting. J. M. Camp, on the other hand, gives his experience as showing a constant loss of 0.25 per cent., irrespective of the total amount of silicon present, with a constantly running cupola, and rather more for short heats. J. Fulton points out that the difference may depend on the method of working the cupola, as it does in the blast-furnace, but he takes the average loss of silicon as 20 per cent., or one-fifth of that originally present.

A number of opinions from various foundrymen have been collected* to show the present position of chemistry in relation to foundry practice in buying and mixing iron. The views expressed are in favour of analysis, and some of the specifications are given. One of these is as follows:—

	Silicon.	Sulphur.	Phosphorus.	Manganese.	Carbon.
	Not less than	Not exceeding			
No. 1 . . .	2.50	0.300	0.50 to 0.80	0.20 to 0.50	3.50 to 4.00
No. 2 . . .	1.90	0.035	0.50 to 0.80	0.40 to 1.00	3.50 to 4.00
No. 3 . . .	1.50	0.045	0.50 to 0.90	0.40 to 1.20	3.50 to 4.00

Another firm sample the pigs very carefully, and store them according to analysis. In calculating the percentage in a casting made from a mixture, a loss of 0.15 of silicon is allowed for, and a gain of 0.030 per cent. of sulphur. Coke is rejected if it contains over 0.75 per cent. of sulphur, of which element 4 per cent. is given up to the iron in the cupola. Sulphur is usually kept down to 0.065, but in any case is kept below 0.090 per cent.

The Use of Aluminium in the Foundry.—J. A. Steinmetz † recommends that pure aluminium should be purchased and made up into ferro-aluminium to save the freight. When used with iron or steel castings, it should be placed in the ladle before the iron is tapped, and the iron should not be too hot. Aluminium up to $\frac{1}{2}$ per cent. increases the fluidity, but at that amount and above it acts in the contrary direction with ordinary foundry iron, but grey iron is rendered less fluid by any addition. The shrinkage is reduced if enough is added. Several authorities are quoted to show that it causes the iron to retain its fluidity for a longer period.

* *Iron Trade Review*, vol. xxx. No. 29, p. 11; No. 30, p. 9.

† Paper read before the Foundrymen's Association, Philadelphia, through the *American Manufacturer*, vol. lx. p. 657.

Melting Iron and Control of Mixture.—According to J. A. Beckett,* in controlling a mixture of iron based on its analysis, it is not usually necessary to watch closely the elements, except silicon and sulphur, especially the latter. Small variations of silicon are easily detected by physical tests if the other elements are constant. Phosphorus increases fluidity, and decreases shrinkage and contraction, so that it is beneficial for irregular castings which can be made with less internal strains, and so are less liable to break. With 0.75 phosphorus, if silicon is about 2.25 per cent., a softer, sounder, and stronger casting is produced than if silicon were alone relied upon for fluidity. Castings made from such mixtures are less liable to break when subjected to shocks. Nearly all the troubles to which castings are liable are ascribed to sulphur, chief amongst them being hard iron and blowholes. Sulphur rarely exceeds 0.060 per cent., and in good coke should not exceed 0.75 per cent. Lime is used as a flux for the ash of the coke, and it also tends to absorb the sulphur. The deleterious effects of sulphur may be partly counteracted by phosphorus, as the metal is more fluid, and remains so much longer in the ladle, whereby gases can escape better. Abnormal shrinkage is also lessened.

Comparative Fusibility of Foundry Iron.—T. D. West † has commenced some experiments on the comparative fusibility of foundry irons, in order to determine the effect of various combinations of the metalloids present. A cupola with central blast and also side tuyeres is used; a central partition reaches nearly to the bottom, which is sloped away to a taphole on each side of one diameter. The two metals to be compared are charged separately on either side, and the behaviour of each as it runs from its own taphole is noticed. In the eight results given, one brand was used in all instances as a standard, and the times required for incipient and complete melting of equal weights were noted. All these with one exception showed that hard irons melted sooner and more quickly than soft irons, showing the effect of silicon. Further experiments are to be made. In the discussion R. Moldenke described the behaviour of two similar pigs, one of hard and the other of soft iron, when thrown on to the bath in a steel furnace. The hard iron held its form, but ran down suddenly, whilst the soft iron melted sluggishly and more slowly.

* Paper read before the Foundrymen's Association, through the *American Manufacturer*, vol. lx. p. 875.

† Paper read before the Pittsburgh Foundrymen's Association, through the *American Manufacturer*, vol. lxi. pp. 8-10; *Iron Trade Review*, vol. xxx. No. 26, pp. 14-15.

Foundry Mixing-Ladle.—Illustrations have appeared * of a mixing-ladle designed for use in conjunction with a cupola. The ladle itself has a capacity of about 1600 lbs., and is supported on trunnions mounted on standards in a line with the taphole. A third standard, also in the same line, carries one end of a shaft, which is connected by a clutch to one trunnion, and is driven by worm-gearing to tip the ladle so as to pour from either side. This clutch connection allows the ladle and outer standard to be turned through a right angle round the central standard as a pivot, so that metal can be run into other ladles direct from the spout of the cupola.

Foundry Facings.—H. F. Frohman † deals with the various kinds of facings used in the mould to give a good surface to the casting. The first of these to be mentioned, although not strictly a facing, is the coal mixed with the sand in order to prevent its fusion, and to burn out so as to vent the mould. The best quality of coal to use is a soft bituminous or gas coal, free from slate and phosphorus. Of facings properly so called, plumbago is one of the best to give a smooth surface. Ceylon graphite is the best quality to use for all kinds of moulding in dry or green sand, and may be dusted or washed on. Stove and other light castings require a double facing—first a heavy facing of graphite and then one of lighter carbonaceous material. Soap-stone facing is sometimes used, and other materials.

Moulding.—R. Grimshaw ‡ gives some illustrated notes on sand-core moulding by machinery in Europe. The cores are built up of short hollow cylinders of sand threaded on a core-bar, the lengths of these cylinders ranging from about 12 to 16 inches. Instead of cylinders, irregular core-forms may be produced by using a properly formed false bottom or foundation in the machine, and square or other shapes are also produced. The lengths are made by ramming the sand round a core-bar in the mould.

Illustrations have appeared § of a special form of chaplet and holder for supporting large cores. The chaplet consists of a triangular prism of cast iron, grooved on its edges so as to melt into the casting readily.

* *Iron Trade Review*, vol. xxx. No. 35, p. 8.

† Paper read before the Foundrymen's Association, through the *Iron Age*, vol. lx. No. 5, pp. 9-10.

‡ *American Machinist*, through the *Iron Trade Review*, vol. xxx. No. 37, pp. 12-13.

§ *Iron Age*, vol. lx. No. 5, p. 14.

The holder consists of a rod held at an adjustable height by a screw socket embedded in the sand.

R. D. Moore * gives as a rule for calculating the pressure of molten iron in a mould, that a column 4 inches high gives an approximate pressure of 1 lb. per square inch. The weighting of the cope can thus be ascertained, but extra strains, such as explosions of gas, have to be allowed for. Some examples of insufficient weighting are given.

Malleable Cast Iron.—G. C. Davis † comments on the small amount that has appeared on the subject of malleable cast iron, ‡ and discusses its chemical composition. The most important change is the substitution of coke for charcoal iron, now that iron low in silicon and sulphur can be produced. It only remains to control the phosphorus and manganese. From a quarter to a half of coke iron is used at present. Silicon should range from 0.60 to 0.90 per cent. If it is below this, the casting is tough but does not machine smooth, and if it exceeds 1 per cent. the casting is brittle. Sulphur as ordinarily present has apparently little effect on the toughness; it usually ranges from 0.04 to 0.12 per cent. Phosphorus is the weakening element, and usually ranges from 0.15 to 0.22 per cent.; above that point the casting is brittle. Manganese is indirectly of great importance, as the castings are dirty, and it seems as if the iron had oxidised when sufficient is not present. The usual amount varies from 0.20 to 0.40 per cent. Carbon varies according to the thickness of the casting and time of annealing. Some typical analyses, taken across a broken face by filing, so as to obtain an average of the inner and outer layers, are as follows:—

Carbon, per cent.	0.15	0.64	1.03	1.58
Thickness, inch	1.8	3.16	5.16	9.16

C. James § describes a special process for treating cast iron. For the purpose, white iron with 2.4 per cent. of combined carbon, 0.4 per cent. of graphitic carbon, and a small proportion of manganese and silicon is used. The castings are placed in a muffle furnace, in which they are subjected to the action of a powerful volatile oxidising agent of secret composition, and maintained at a temperature slightly below fusion for five or six hours. The product can be forged and hardened, and shows a remarkable increase in tensile strength. In the discussion

* *Iron Moulders' Journal*, through the *Iron Trade Review*, vol. xxx. No. 33, p. 15.

† Paper read before the Foundrymen's Association, through the *American Machinist*.

‡ See *Journal of the Iron and Steel Institute*, 1897, No. 1. pp. 154-166.

§ *Journal of the Franklin Institute*, vol. cxliv. p. 80.

which followed, doubts were expressed whether the result was not due entirely to the annealing rather than to the oxidising agent employed.

Cast Joints for Rails.—I. R. Newkirk * describes the method for making cast joints for tramway rails. The apparatus required is a cupola with spouts and slag-hole mounted with gimbal joints on a strongly built waggon. An enclosed electric motor, mounted on the truck and supplied with current from the line wire, drives a fan supplying the blast to the cupola through a flexible pipe, which allows the swinging of the cupola to a perpendicular position on varying gradients. No special charging is required, it only being necessary to use a strong mixture of iron, and hot enough, so that it will thoroughly amalgamate with the steel rails. Specially built heaters are used to dry the rail ends, which are then scraped and cleaned as bright as possible. The rails are then surfaced and lined up, a screw clamp is put on, and a headpiece is placed on the rails covering each end. The iron is poured in on one side, amalgamating with the steel rails. After a mould is poured and a sufficient time has elapsed for the iron to set, the clamp and chills are removed. An electric grinding machine is used for surfacing the top of the head of the rails. The joints are generally made in warm weather when the rails are expanded to their extreme limit. About every 400 feet an expansion joint is made, or all the joints are made solid, so that when the rails contract in cold weather some joint will break. The rails will then spread perhaps as much as 2 or 3 inches. The joint is broken off, and a small piece of new rail set in and a new joint made or cast on.

The Pennsylvania Railroad is now experimenting with 100-foot rails, and the Lehigh Valley Railroad with 60-foot rails, and very many street railways use 60-foot rails, showing a growing tendency to have fewer joints to wear out and reduce the life of the rails. The cupola, drawn by five horses, is placed about 400 yards from the farthest joint to be poured. A gang of sixty men make 102 welds in a single night. Illustrations of the plant and of the rail joints have also appeared.†

Mending a Broken Roll.—An illustration has appeared ‡ of a method for casting a new journal on a broken roll. The roll is set

* Paper read before the Foundrymen's Association, Philadelphia, through the *Iron Age*, vol. lx. No. 11, p. 10; *Industries and Iron*, vol. xxiii, p. 319.

† *Engineering News*, vol. xxxviii. p. 246, with one plate; *Iron Trade Review*, vol. xxx. No. 37, p. 15.

‡ *Uhland's Maschinen Constructeur*, through the *Iron Trade Review*, vol. xxx. No. 33, p. 9.

upright with its broken surface a few inches above the foundry floor. A coke or charcoal fire is used to heat the end to as high a temperature as possible. The fire is then removed, the surface cleaned, and a mould placed in position. Molten iron is then run through the mould from above, issuing by a spout near the bottom, until the fractured surface is well softened. The spout is then closed, the mould filled, and the metal allowed to solidify. It has been pointed out by W. J. Richards* that this method is not new.

Chilled Iron Castings.—E. H. Putnam † describes the appearance and characteristics of chilled iron as compared with grey iron. Chilled iron is less strong than grey iron, although it is harder, so the mixture must be chosen to give sufficient iron without sacrificing strength. The author questions whether chilling iron melts at a lower temperature than softer or grey iron; it certainly requires more fuel to bring it to the right degree of fluidity and temperature for casting. The use of charcoal iron is strongly upheld, because its chilling characters are marked and uniform. Coke iron, to give a good chill, must be so high in combined carbon as to render the castings weak.

E. C. Pechin ‡ discusses the relative merits of charcoal and coke iron for chilled castings, and mentions a furnace at Dunbar, Pennsylvania, which had been running on forge iron, but suddenly produced foundry iron containing graphitic carbon over 3 per cent., only a trace of combined carbon and sulphur, 0·4 of phosphorus, and 0·45 of silicon. This iron took a heavy chill.

Castings for Cylinders and Valves—Some specifications for the manufacture of cast cylinders and valve-facings have appeared. § Two analyses are as follows:—

Si.	Mn.	P.	S.	Combined Carbon.	Graphitic Carbon.
1·51	0·33	0·65	0·068	0·62	2·45
...	0·35	0·6 to 0·9	0·07 to 0·12	0·6	...

The first is made from a mixture of 20 per cent. steel castings, old springs, &c., 20 per cent. No. 2 coke iron, and 60 per cent. scrap.

* *Iron and Coal Trades Review*, vol. lv. p. 387.

† Paper read at the Annual Convention of the American Foundrymen's Association, through the *American Manufacturer*, vol. lx. pp. 763-764.

‡ *Tradesman*, through the *American Manufacturer*, vol. lxi. p. 79.

§ American Railway Master Mechanics' Association, through the *American Manufacturer*, vol. lxi. p. 80.

Iron Pipe-Founding.—S. Grooves * gives some notes on iron pipe-founding. In Europe it is stated that the practice is to cast socket and spigot pipes with the socket downwards, but in the United States this practice is reversed. Pipes of 1 to 2½ inches diameter are cast on banks at an angle of 30°, and a cast iron core-bar is used. Pipes from 3 inches upwards are cast in oval pits arranged in series over a foundry 250 to 300 feet long. In an oval pit with flasks fixed to the walls it is possible to cast eighty 3-inch pipes 9 feet long in a day. Methods of blacking and of drying the moulds are described. For the latter, hot gas generated outside the shop is sent through the pipe pits by a blower. A description is also given of the manufacture of the cores, and the use of metal direct from the blast-furnace is mentioned, a partition running nearly to the bottom of the ladle serving to keep out the dirt. High phosphorus iron is well adapted for the work. The testing of pipes is also discussed.

According to S. S. Knight,† the making and maintenance of the core for pipes up to 6 inches is a very large item in the cost of pipe manufacture. As a rule, these are made with loose hay or hay-rope wound on the core bar and covered with clay, and after drying, the second coating and facing are applied. In Fletcher's method the hay is dispensed with, and a porous centre is obtained by the use of a mixture of starch and sawdust. The bar is coated with this material, dried, and the final facing is then applied directly, the clay being omitted. Larger and stronger core bars can thus be used.

Foundry Costs.—H. Roland ‡ deals generally with cost-keeping methods in the machine-shop and foundry. The elements of cost and the influence of wage systems are first discussed, piece-work being especially considered under its various aspects.

* Paper read at the National Convention of Foundrymen, through the *American Manufacturer*, vol. lx. pp. 766-767.

† *Journal of the American Foundrymen's Association*, through the *Engineering News*, vol. xxxviii. pp. 204-205.

‡ *Engineering Magazine*, vol. xiv. pp. 56-63.

PRODUCTION OF MALLEABLE IRON.

History of Iron.—On the agenda of the Cumberland and Westmoreland Antiquarian and Archæological Society, at their meeting in July 1897, was a paper by W. G. Collingwood and H. S. Cowper on a bloomery at Coniston.*

Direct Reduction from Ores.—W. F. Berner,† in a paper read before the Russian Institute of Mining Engineers, describes and illustrates a proposed furnace plant for direct reduction. It is a shaft furnace, with tuyeres at different levels, and divided into halves by a partition, in a way somewhat resembling some of the older German lead blast-furnaces. The two halves are connected with each other. A mixed producer gas is used in part as fuel. On one side of the furnace pig iron is made, on the other the iron ore is reduced to the metallic state without coming in contact with carbon. The reduced metallic iron, meeting the pig iron lower down in the furnace, dissolves in it, the product being a steel which is run direct into a reverberatory forming a "fore-hearth" to the shaft-furnace, and in this its treatment is then completed. Both solid and gaseous fuel is thus used in the furnace—solid fuel being burnt on one side by the aid of hot blast and in admixture with the ore; an excess is, however, to be avoided. The mixed producer gas used on the other side for the reduction of the ore is first preheated in regenerators. The mode of working the furnace is dealt with, and the theory of the process discussed.

Melting Wrought Iron.—C. Vickers‡ describes some experiments made on melting wrought iron in a coke-hole preparatory to erecting works for the manufacture of Mitis castings. The furnace used was an old boiler shell, lined so as to make a coke-hole 36 inches

* Noted only in *Antiquary*, but paper not given, vol. xxxiii. p. 259.

† *Stahl und Eisen*, vol. xvii. pp. 557-564; ten illustrations.

‡ *Iron Age*, vol. lx. No. 8, pp. 11-12.

deep by 26 inches in diameter, and connected to a 40-foot stack. The crucibles rested on a base 9 inches high, made of firebrick, and placed on the fire-bars before lighting. The fire was allowed to burn down level with the base, and then the crucible was put in charged with horse-nail clippings and boiler punchings. After gently heating at first, the temperature was kept up for five hours by charging with coke and poking down at intervals, so as to keep a solid mass of fuel. This precaution is very necessary in order that the lower part of the crucible may be properly heated in order to fuse the metal, to prevent scaffolding, and to obviate the great tendency of the crucible to stick to the base.

Native Iron Smelting in India.—According to R. B. Foote,* iron smelting is now carried on in three villages in the Bellary district in the Madras Presidency. Soft rich hæmatite obtained in the neighbourhood is used, and the iron is largely worked up into sugar-boiling pans, which are very creditable pieces of smith-work.

The History of Iron.—Continuing his "History of Iron," L. Beck † deals with its history in the eighteenth century. During this period peace was less disturbed than it had been by constant warfare in the previous century, steam-power replaced water-power, and coal and coke replaced wood and charcoal on a wider scale. The literature of the metallurgy of iron dates from this period. In 1722 Réaumur wrote his famous book "*L'Art de Convertir le Fer Forgé en Acier et l'Art d'Adoucir le Fer Fondu*." Then in 1734 Swedenborg published his work "*De Ferro*," which is really the first text-book of iron metallurgy. Then in 1782 came Rinman's well-known book "*Försök till Järnets Historia*"—his so-called "History of Iron," which in reality treats of its metallurgy. The "*Voyages Métallurgiques*" of Jars, published in 1774–81 at Lyons, forms an interesting and important record of that period. The phlogiston theory was not finally abandoned till Lavoisier overthrew it in 1783, and the chemistry of the metallurgy of iron was little understood.

The author quotes the statement of Lord Sheffield, that if Cort's discovery, together with the steam-engine of Boulton and Watt, and Lord Dundonald's improvements in the manufacture of coke, should prove of lasting value, their value to England would be greater

* *Memoirs of the Geological Survey of India*, vol. xxv. pp. 191–193.

† *Die Geschichte des Eisens*, vol. iii. Brunswick, 1896.

than that of the lost colonies of North America, for they would give to England the complete control of the iron trade. The discovery of crucible steel by Huntsman is dealt with. The manufacture of cement steel and of malleable castings is also referred to, and then the progress of the iron-founding industry is passed in review. This received an important impulse by the introduction of the method of remelting the pig iron, as at the beginning of the century, almost without exception, only direct castings were made. At the Carron works Jars saw five reverberatory furnaces used for remelting pig iron, and these were named *cupolas*, from the dome-like character of the roof. Shaft-furnaces, to which the name *cupola* was also generically applied subsequently when used for the same purpose, were not introduced until the eighties, their originator being J. Wilkinson. For decades afterwards they were called "Wilkinson furnaces."

FORGE AND MILL MACHINERY.

The American Blooming-Mill.—R. Crooker * traces the development of the blooming-mill in America. In England, in the early sixties, the Bessemer ingots were hammered and not rolled direct. J. Ramsbottom brought out his duplex hammer with two hammers moving towards each other, but these were not altogether suitable, so his cogging-mill was brought forward. In many respects this resembles the later blooming-mills, and many other inventors were also occupied in the same direction. Up to 1857 the practice for heavy work had been similar in America and England, namely, two-high non-reversing mills, but in that year J. Fritz, in America, first put in use his hanging guide, which made the three-high mill possible, and in a few years all mills in that country were made three-high. In England the practice developed into reversing mills with clutch motions, and later reversing engines. The blooming-mills in both countries followed their own rolling-mill designs, and adhered to them for many years. It was not until 1871 that the first blooming-mill was built in America. This was at Troy, and was three-high with fixed top and bottom rolls and a movable middle roll, carried by a pair of bolsters raised and lowered by screws. Six months later G. Fritz put to work a three-high mill with the middle roll fixed and the others movable. In this design it was only necessary to move the rolls to their full extent for the first pass. The important feature of this mill was the tables, which were raised and lowered by hydraulic power and had driven rollers. Combined with this table was a manipulator. In the next year, 1872, the first reversing mill was built in the United States; the reversal was obtained with friction clutches and gearing. Crab clutches never have been used for this purpose in that country, but at the time there was much discussion as to the forms of clutches.

* Paper read before the Engineers' Society of Western Pennsylvania, September 1897, through the *Iron Age*, vol. lx. No. 14, pp. 16-18; *Iron Trade Review*, vol. xxx. No. 38, pp. 13-16; *Engineering News*, vol. xxxviii. pp. 211-213.

These mills at Troy, Cambria, and Cleveland were the pioneers, but only the Fritz mill affected the design of later mills, and nearly all the eight works built between 1871 and 1876 followed this design, and only varied in minor details. Increasing production soon overtaxed the capacity of the casting-pits, so the Cambria Iron Company in 1878 determined to make the ingots larger, and to bloom them in a mill of English construction with reversing engines. The tables were, however, of American design, with large rectangular frames, carrying the gudgeons of loose rollers which rested on solid tracks. With this construction the ingots moved twice as far as the table when its frame was reciprocated. The manipulator consisted of arms projecting over the table, and worked by hydraulic cylinders on each side. None of the reversing mills were equipped with manipulators for seven years afterwards, although this one was highly successful.

During this decade open-hearth steel was rapidly advancing, and the Schœnberger mill, the first reversing mill for this metal, was built in 1879; but the opinion in favour of three-high mills was very persistent, and several of this type were built, though the designs varied very considerably, as they were not constructed according to the Fritz method, for which the patent was still alive.

The beginning of the decade 1880 to 1890 saw great development and activity in the steel trade. All the mills were built larger and stronger, and two mills, a three-high at Bethlehem in 1884 and a reversing mill at Cambria in 1885, were made 48 inches in diameter. Since then, however, none have been set up over 40 inches. The three-high mill has reached a fixed standard, and no appreciable changes have been made in it since the one built at Chatanooga in 1878, and embodying all the present ideas. In these mills the rolls are all fixed, the tables are raised and lowered by a horizontal cylinder connected with L cranks and links, and the table rollers are driven by an independent reversing engine through gears carried by a lazy tongs. Only one serious modification of the three-high mill has been seriously attempted, and that for the purpose of combining with it the advantages of the two-high mill. In this mill, built at the Otis Works at Cleveland, the bottom roll was fixed, the top roll counterbalanced and worked with screws, whilst the middle roll was thrown up and down between passes, as in a three-high plate-mill.

The three-high mill attained its highest development at about the time when the two-high mill began its career, and the latter has continuously developed for twenty years, until it seems to have reached

its highest point of development. The present table frames are substantial cast iron bed-plates, with bearings bolted on and water cooled. The rollers are steel castings, with the necks cast on, or with a body of cast iron and forged axles. They are driven by bevel gear from a separate engine for each table, coupled direct to the line shaft. Manipulators have come into general use since 1890, but the designs are still very various. In the rolls themselves the windows of the housings have been widened, so that the rolls may be changed through them, and hydraulic counterbalancing is used for the top rolls. Hydraulic and sometimes electromotors are used for the screws, and in the latest mills no gearing is used between the rolls and engine crank shaft.

American Rolling-Mills.—An illustrated description of the plant at the various works controlled by the Illinois Steel Company has recently appeared,* together with some account of the blast-furnaces and steel plants. The number of mills and their dimensions and the size of the engines are given. In the rail-mill at the South Chicago Works extra passes for billets are turned in every set of first and second roughing rolls, and the ingots can be moved to one or the other for conversion into billets or into rails. The other works dealt with are the North Chicago Works, the Union Works, Chicago, the Milwaukee Works, and the Joliet Works. At the latter there are two Garrett rod-mills, with a continuous roughing train and heating furnaces.

Detailed drawings have been published † of a reversing gear for rolling-mills, in which Lindsay's coil clutch is used. This is constructed of a helix of square steel, so arranged that the tail end may be made to grip or release the shaft by coil friction. The grip is taken on a chilled cast iron sleeve on the shaft, and in the type used for transmitting up to 2000 horse-power and over, both coil and sleeve are turned parallel, one being a little larger than the other. To put it in action, the coil, by pressing one end, is wound up slightly to obtain the initial grip, which then tightens itself. On releasing the pressure the clutch liberates itself. Two clutches are used in the mill, one driving direct and the other through a train of spur gearing for reversing the motion.

Illustrations have appeared ‡ of two types of rolling-mill engines made by a firm in Philadelphia.

* *Iron Age*, vol. lx. No. 3, pp. 6-12; *Iron Trade Review*, vol. xxx. No. 28, pp. 11-24.

† *Engineering*, vol. lxiii. pp. 604, 605, 606.

‡ *American Manufacturer*, vol. lx. pp. 835-836.

A Three-High Rolling-Mill.—A description has appeared * of a rolling-mill at the Maximilianshütte, near Rosenberg, in Bavaria. The mill was built in 1892, and has since then been in constant use. By the aid of tables provided with driven rollers, and by other means, the ingot is passed into the roll, lifted or lowered, turned over, &c. For the working of the whole of these appliances and the engine driving them, only two men are required, but a third workman stands behind the rolls and helps occasionally. Full details are given.

Wire-Rod Mill.—An illustrated description and plan of the twin rod-mill at the Joliet Works of the Illinois Steel Company has recently appeared.† The recent improvements comprise a continuous mill for breaking down 4-inch billets to a size of $1\frac{1}{2}$ inch, which are fed to the rod-mills alternately. The billets used are 76 inches long and weigh about 315 lbs. each. They are delivered hot by conveyors to wash heating furnaces fired with oil, a special pneumatic charging and withdrawing device being employed. The heated billets are sheared into two and then roughed down into a $1\frac{1}{2}$ square bar by one or other of five passes in a continuous train of six sets of two-high 18-inch rolls placed in a straight line and driven from a single engine at proportionately increasing speeds. As the bars emerge they are directed right or left at right angles by troughs to the continuous rod-mills, or they may be sent straight on to a hot bed in case of emergency, where they would be cut up into small billets. The old mill on the left has one stand of 16-inch rolls, three of 12-inch, four of 10-inch, and four of 9-inch. The new mill on the right has one stand of 16-inch rolls, three of 14-inch, four of 11-inch, and four of 10-inch. Six rods may be worked at once in the finishing rolls, from which the rod issues to the reels at the rate of 1200 feet per minute. The reels are of the Edenborn design, in which the horns are withdrawn by pneumatic power to allow the coil to fall off.

Pit Furnace.—Illustrations have appeared‡ of a pit furnace for heating ingots, arrayed so that each pit is independent of the others and under separate control, so as to be heated uniformly. Valves with water circulation are used and the furnace is constructed to take forty-eight or sixty ingots.

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xl. p. 1; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 203.

† *Iron Age*, vol. lx. No. 8, pp. 1-4, with plates.

‡ *American Manufacturer*, vol. lxi. p. 295.

Magnets for Hoisting Purposes.—In the plate-mill of the Illinois Steel Company,* electro-magnets are used instead of tongs on the crane for picking up plates. Double-pole magnets, of which illustrations are given, handle five tons with safety and require a current of about four amperes at 240 volts. These magnets were used for billets, but unsuccessfully, as they were too much entangled, but they work well with plates. It is found that several plates are picked up at once, but by suddenly cutting off the current for an instant, the lowermost plates are dropped, and this is repeated until only one plate remains attached. A concentric pole magnet is used for handling hot plates and ingots, and no difficulty is found with weights of 6000 to 8000 lbs. at a low red heat. The work to be handled must be of such shape as to give a good contact.

Steel Roofs for Mill Buildings.—A. E. Duckham † discusses the various forms of purlins, coverings, and methods of calculating stresses in the roofs of mill buildings.

* *Iron Age*, vol. lx. No. 7, pp. 1-2.

† *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xiii. pp. 310-322.

PRODUCTION OF STEEL.

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I.—THE CARBURISATION OF MALLEABLE IRON.

Crucible Steel-Making in America.—In the United States but little attention has been paid to the manufacture of crucible steel, and most of the finer grades are imported. A large quantity of that now made is prepared according to the formulæ of thirty years ago, but with inferior material. When the manufacture was first introduced, imported Swedish iron and leaf spring scrap were used, but local scrap is now used; and as this spring steel is made from Bessemer steel, containing both sulphur and phosphorus, instead of from crucible steel of fair quality, the grade has deteriorated. Greater use is now made of chemical analysis, and so many advances are being made. Carburising imported iron by cementation was the first to disappear, although some works use the process for domestic iron. Charcoal iron made in the country was first substituted for imported iron, and then its place was taken by puddled coke iron or muck-bar, and a correspondingly inferior article was made. Much attention is given to the introduction of alloys into the crucible, and the process is generally attracting greater attention.*

A. C. Cunningham† states that ordinary steel castings are often stamped as cast steel, and then proceeds to discuss the requirements of the former.

* *Iron Age*, vol. lx. No. 5, pp. 5-6.

† *Railroad Gazette*, vol. xxix. p. 449.

The Care of Crucibles.—J. A. Walker * describes the precautions that should be taken in using graphite and other crucibles for steel melting. They should be kept in a dry place, and should be carefully dried before use by heating them to 250° or 300° C. very evenly. In annealing, the same care should be taken to see that the pots are evenly heated, and then they should be glazed by firing them as rapidly as is consistent with safety in the first heat. A reducing flame in place of an oxidising flame should be employed for graphite crucibles, and the proper glaze is a great protection against burning. The tongs should fit the crucible properly, and should hold it just below the bulge, in order to obviate the necessity for gripping it too tightly. Spade-ended tongs are useful, as they clear the sides from the fuel better. The crucible should be completely emptied before cooling, so that no metal remains in it to solidify. For cooling, a dry place is necessary, and gentle handling is requisite. In filling the pots, the charge must not be packed too tightly, as the expansion of the metal may crack the crucible. Consideration must be given to the nature of flux and fuel in choosing the crucibles, so that they may not be eaten away too quickly.

Recent Methods of Steel Manufacture.—R. M. Daelen † observes that the question, "Which will be the method of the future for the manufacture of iron?" cannot yet be answered with certainty. It is probable, he considers, that existing methods will still maintain their present position of superiority for a considerable time. This is all the more probable as the various new processes, whether inventions or improvements, have for a long time past been mainly in two directions, neither of which is new. The result has, consequently, been that it is chiefly modifications of existing methods that have resulted. The first line of thought has been to decompose the iron oxide of the ore by heating in reducing gases, and then separating the reduced iron from the other substances mixed with it by the aid of fusion. The second has kept the blast-furnace as its basis, and has dealt with the combustion of the carbon, silicon, and other foreign bodies in the iron with a view to effect this in some simpler or more economical way than has thus far been customary. The chief difficulty with which the first of these kinds of methods has had to deal has not lain in the

* Paper read at the Convention of the American Foundrymen's Association, Detroit, May 10, 1897.

† *Stahl und Eisen*, vol. xvii. pp. 401-403.

reduction of the iron oxide, but in the prevention of the re-oxidation of the iron sponge after reduction. The Carbon Iron Company of Pittsburgh effects this by the addition of an excess of a hard-burning graphite, and then a rapid transfer to the fusion-hearth. Although the out-turn and economic success of this company is not inconsiderable, still nothing is known of any great spread of this process up to now, and it may be concluded from this that the process is only suited to certain local conditions. In 1896 attention was drawn to a process in Sweden in which the ore was to be reduced as above in a shaft-furnace, and then to immediately fuse the sponge by means of the electric arc, and then to transfer it to the bed of an open-hearth, where it was to be carburised under the protecting layer of slag. The method, as far as its various details go, is possible. It is not likely, however, to become a serious competitor with the present methods. The author points out the objections to these methods, and suggests means by which some of them might possibly be overcome, especially in connection with the loss of heat by the fused metal; and some older experiments by Sir Henry Bessemer are referred to.

The relative values of the open-hearth and Bessemer processes are discussed, and the joint Bessemer open-hearth process is also considered, as well as these several processes themselves and their modifications. Reference is also made to the blowing-in of powdered ore into a Bessemer converter—an idea the author is working out in conjunction with L. Pszczolka. A side-blast is intended, and several points in connection with this proposed process are mentioned. The preliminary experiments have proved successful. So long as adequate quantities of carbon are left in the metal, there is no danger of any large quantity of iron being burnt. Various advantages resulting from a preliminary treatment of pig iron by such a mixed ore-blast process are mentioned.

II.—THE OPEN-HEARTH PROCESS.

The Open-Hearth Process in Germany.—Dealing with the open-hearth process in a paper read before the Verein Deutscher Eisenhüttenleute, Springorum* refers to the extremely rapid progress which the basic open-hearth process has made in the past fifteen years. The result has been that the arrangements of basic open-hearth plant show

* *Stahl und Eisen*, vol. xvii. pp. 396-401; eight illustrations.

far greater diversity than exists in the arrangements of basic and acid Bessemer works. It is mainly with the basic open-hearth plants that the author deals. He points out that, in the first place, the gas-producers are now very different from those originally used. The old form of the Siemens producer with its sheet-iron connections is disappearing more and more, and is being replaced by shaft-producers of variable form with walled gas leads and forced blast. Sometimes these producers are metal-cased, and sometimes not. The metal-cased round shaft-producers seem to be those best liked. The fire-grate is either flat or stepped, and sometimes the producer is provided with a cup and cone. An important point in connection with the variable type of shaft-producer lies in the way the ashes are removed. Producers without firebars are in successful use at various places. In these, by the use of fluorspar and calcium carbonate, the ash is rendered thin-fluid, and is then tapped off. An attempt to introduce this process into Westphalia proved a failure. A forced blast is now used in place of the former steam method, affording the advantage that the steam and air are independent of each other, and can be regulated separately as required. The bottom-blast pressure varies from 3 to 4 inches of water, and, using this pressure in a producer 13 feet high and $6\frac{1}{2}$ feet in diameter, about 7 tons of Westphalia coal are gasified per day. The use of forced blast in the open-hearth is only occasionally adopted. The method of charging the producers is considered, and the question of labour is also dealt with. The gases of these shaft-producers contain up to 28 per cent. of carbon monoxide and 12 per cent. of hydrogen, and according to the distance of the producers from the open-hearths, they reach them with a temperature of 500° to 800° C. The use of a forced blast in these producers leads to the formation of a considerable quantity of dust and soot, but the use of dust-chambers between the producers and the furnace has practically led to all difficulties from this source being avoided. The author mentions another producer arrangement which is stated to have yielded, with superheated steam and pre-heated air, a gas containing 39 per cent. of carbon monoxide and 14 per cent. of hydrogen. This is the Taylor producer with Bayard attachment and Heurtey-Fichet arrangement. The question of the gas-valves is then dealt with, and the author next passes to a consideration of the other portions of the plant. Every open-hearth, he points out, must have its own powerful stack. The separation of the different parts of the furnace from one another, and the ready accessibility of the whole is

then referred to, and the arrangement of the gas and air channels is also dealt with. The use of slag-collecting chambers, not filled with bricks to keep any drops of slag from choking up the brickwork is referred to, and the new Siemens modified form of the open-hearth itself is also dealt with. It has been found necessary to revert to the method of bringing gas and air into contact with the charge, as the parallel system was found to diminish to too great an extent the rate of the oxidation and of the dephosphorisation. In Germany the hearth, and the walls for 6 to 8 inches above it, are made of stamped dolomite mass or of the pressed bricks. The isolating layer between this and the roof is usually made of magnesite bricks or of magnesite tar material. The author knows nothing as to the use of magnesite bottoms. For dolomite bottoms to stand 1000 to 1500 charges, or even more, is now by no means a rarity. For acid-lined furnaces 600 to 700 charges is placed as a maximum, though at Graz 800 are stated to be worked off without necessitating repairs. Basic furnaces using scrap, and with a low phosphorus percentage in the charge, last up to 500 charges, but a higher percentage of phosphorus and the larger use of pig iron shorten the life of the furnace. The Schönwälder type of furnace will stand 1000 charges, despite the use of a large percentage of phosphoric iron. At present seventeen of these furnaces are in use at thirteen works. With regard to the size of the open-hearths, a capacity of 15 to 20 or 25 tons is preferred in Rhenish Westphalia. In the United States turning or tipping furnaces of large size are in use, and the Illinois Steel Company has recently built one of 75 tons capacity. The tipping furnaces, the author observes, possess a number of advantages over those of the ordinary type. These he briefly mentions. The use of mechanical charging appliances is next touched on, and then the question of the casting pits and method of casting generally is passed in review, and other points are briefly referred to.

W. Schmidhammer,* considering the points raised above, observes, in reference to the question of the best gas-producer for use in the open-hearth process, that in 1893, after having for several years attempted to work with Seiller shaft producers and slag fusion, he gave this up and adopted in its place a form of producer which he now illustrates. It possesses a flat grate with square bars of 1·6 inch side, and above this at a height of 5·9 inches is another false grate, the bars of which are placed at right angles to the others. The air enters

* *Stahl und Eisen*, vol. xvii. pp. 622-628; three illustrations.

through a channel inside the sheet casing, passing down the walling from the top to below the fire-bars. Two producers were used for each 7-ton furnace. When the Reschitza Works were reconstructed in 1896 the author found it necessary to abandon these producers, and to adopt a different arrangement, placing four shafts together in one block. This multiple form of producer is also illustrated. Flat grates were again used, as these have been found to work well with briquettes. The author next proceeds to consider the open-hearth itself and its arrangements, and he draws attention to the desirability of keeping the furnace and the several producers well separated from each other. The method of putting in a magnesite bottom is described, and the author passes to a brief consideration of the question of the use of the various mechanical labour-saving appliances, and to that of molten metal. Metal to be run direct from the blast-furnace into the open-hearth should not be too grey, that is to say, it must not contain too much silicon, as in that case there would be no appreciable saving in time as regards the duration of the charge in the furnace. For high silicon iron a preliminary blow in the Bessemer converter is desirable, and the author refers to the history of this process, which was subsequently introduced into the United States under the name of the "Duplex" process. The partial preliminary decarburisation in the converter, as suggested by Kupelwieser, in addition to desiliconising, is also mentioned. This process has been adopted in practice, and is still in use. Such pre-treated metal should, however, be used at once, and not cold—after first casting into ingots, that is. Other points are also discussed.

S. Stein * draws attention to the fact that the greatly increased use of gas necessitates care, as carbonic oxide poisoning is a constant danger. The danger is the greater as the gas can neither be seen nor felt nor smelt, yet on breathing it rapidly deadens the action of the brain and decomposes the blood. Death ensues when the volume percentage of carbonic oxide in the air breathed reaches 17.33. The author draws attention to the use of oxygen as an antidote. This is to be pumped, if necessary, into the lungs. Its action is fairly rapid, provided the person poisoned is not nearly at the point of death. At every works, therefore, where gas is used, there should be kept cylinders of compressed oxygen and also a breathing attachment.

The Bertrand-Thiel Process.—In a paper read before the Verein Deutscher Eisenhüttenleute the Bertrand-Thiel process is described by

* *Stahl und Eisen*, vol. xvii. pp. 516-518.

O. Thiel.* He refers in the first instance to the difficulties experienced in the open-hearth process when it is a question of dealing with charges containing a large percentage of pig iron, especially, too, if this is rich in phosphorus and silicon. The process becomes so slow, that, with a 15-ton furnace, and a charge containing 80 or 90 per cent. of pig iron with 1 per cent. of phosphorus, under the most favourable circumstances only two charges could be worked off, while the output would at best be but 12 tons. The disadvantages resulting in this way are avoided by the combined process, and one can, by its aid, work off readily charges containing any desired percentage of pig iron, and pig iron of any composition, while ensuring a large out-turn.

The method consists in the main in working two or three open-hearths in unison, so that the whole process is not carried out in one furnace only, but divided among several, placed at different levels. In this way the contents of a furnace lying at a higher level can be readily transferred, with a simultaneous elimination of the slag, to a furnace lying lower down, the latter then completing the working off of the charge. The author then describes in detail the method as used at the Kladno Works of the Prague Ironworks Company.† Here two basic open-hearths are in operation, one of 13 tons discharging into a 24-ton furnace lying below and connected with it by a 36-yard runner. The process consists in charging the pig iron into the smaller furnace whilst the scrap is charged into the larger. If it is desired to work with a very high percentage of pig iron, it is necessary to charge some of it into the lower furnace as well as into the upper one, metal low in silicon and phosphorus being selected for this where possible. When the charge in the upper furnace has settled down, it is tapped into the lower furnace, this tapping taking place about two hours after the latter has been charged. A somewhat violent reaction ensues, and the formation of the slag, and the completion of the process generally, is greatly assisted in this way. The metal as run from the upper furnace is very hot, showing this by giving off brown fumes to a large extent, just as in the basic Bessemer process. After one or two hours the mixed charge in the lower furnace is ready, and is finished off in the usual manner. The joint working of the two furnaces is accompanied by no practical difficulty, and the furnace bottoms do not need repairing. In tabular form are given full details as to the results obtained with a large number of charges, the percentage of pig iron

* *Stahl und Eisen*, vol. xvii. pp. 403-418, with numerous illustrations.

† *Journal of the Iron and Steel Institute*, 1897, No. I. p. 115.

varying up to as much as 94 per cent. Its composition also varied greatly. The tables show (1) the composition of the charges in the upper and lower furnaces; (2) yield and loss; (3) chemical composition; (4) duration; (5) testing results; (6) the joint production of the two furnaces in twenty-four hours working together; and (7) their joint production when working separately. This latter was 75 to 100 tons working separately, and 100 to 110 tons when working together. Among analyses given under (3) are the following:—

	Carbon.	Phosphorus.	Manganese.	Silicon.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Metal charged	1.39	0.20	1.02	0.23
Product	0.062	0.044	0.288	...
Metal charged	1.36	0.32	0.88	0.27
Product	0.084	0.036	0.314	...

In a large number of instances analyses are given showing the composition of the metal as tapped out of the upper furnace and run into the lower one. This metal as tapped contains:—

Carbon.	Phosphorus.	Manganese.	Silicon.
2.67 to 0.923	1.032 to 0.021	0.323 to 0.072	0.09 to 0.024

The pig iron as charged into the upper furnace contains in the cases to which the above results refer:—

Carbon.	Phosphorus.	Manganese.	Silicon.
3.80 to 2.18	2.50 to 0.25	3.27 to 0.34	1.00 to 0.60

At Kladno, however, the furnaces were not properly proportioned in size to each other, and the best had to be made of faulty conditions. Where it is desired to work under constant conditions and with a pig iron containing from 1 to 2 per cent. of phosphorus, it would be well to work with furnaces differing by about three tons in capacity the one from the other. In this way the addition of silicon to the lower furnace is avoided, or, at least, reduced to a minimum. The author then proceeds to discuss in detail assumed cases in which the conditions vary, and shows how the process may be applied in these instances, giving examples from actual practice in proof of his statements. Analyses of the slags produced and of the raw materials charged are also given. The process admits of the production of a slag of much value. Sketches of the arrangement of the plant are shown, and in

conclusion the author summarises a number of advantages possessed by this process over the ordinary process. These consist in the possibility of obtaining a high yield from a charge containing a high percentage of pig iron of any composition, using fluid metal, high yield, reduction of furnace repairs, less lime, less fuel, better utilisation of the furnace capacity, more rapid charging, production of slag rich in phosphorus, and others. It is pointed out, too, that it can be applied to any existing plant.

In the discussion which ensued H. Wedding drew attention to the recent paper by P. C. Gilchrist on this process. The advantages connected with an increased production, he pointed out, are evident. The source of the high temperature attained he discussed at some length, giving tables showing the elimination of the different elements at different temperatures in the puddling, Bessemer, and open-hearth processes. The advantages of a high temperature are evident from these, but he finds it difficult to understand whence in this new process the increased heat has its origin unless it be in extra coal consumption, which, however, the author states not to be the case.

O. Thiel,* in further describing this process, again draws attention to its advantages over the ordinary process, pointing out that it leads to a considerable saving in lime, and to a much smaller quantity of slag being produced. The process itself is much more rapid, and consequently for a given plant the production much higher, with a reduction in the fuel used. The furnaces, too, are not subjected to the same amount of wear and tear as in the ordinary process, while the yield is a very high one. With regard to this point the author gives the following results obtained at Kladno. The pig iron used contained :—

Carbon.	Phosphorus.	Silicon.	Manganese.
3·8	1·5 to 1·6	1·0	1·0

Swedish magnetite was also used. The charge was as follows :—
Upper furnace, 11·5 tons pig iron, 1·9 ton ore, 0·8 ton limestone.
Lower furnace, 1 ton ore, 0·48 ton lime, of ferro-manganese 0·05 ton was used. The yield was 12·032 tons, or 0·482 ton more than the weight of the pig iron charged, this excess amounting to 4·17 per cent. The following samples were taken :—

* *Stahl und Eisen*, vol. xvii. pp. 733-735.

	Carbon.	Phosphorus.
	Per Cent.	Per Cent.
Metal tapped from upper furnace	1.77	0.627
From lower furnace after 45 minutes	0.424	0.022
Before charging the ferro-manganese	0.078	0.043
Finished product	0.058	0.049

The finished product contained 0.263 per cent. of manganese. It had a tensile strength of 23.5 tons per square inch, with an elongation of 31.5 per cent. The fusion-time in the upper furnace was four and a half hours, and in the lower an hour and twenty-five minutes. A second similar charge showed an excess of finished product of 4.39 per cent., the fusion-times being four hours in the upper furnace, and one and a half hour in the lower furnace. In both cases the ore and lime additions were made to the lower furnace about forty-five minutes before tapping the upper furnace. The ore consequently yielded 70 per cent. of iron.

With regard to the joint use of an acid-lined converter and a basic open-hearth, as recommended by W. Schmidhammer, the author considers that such a method can be of but very limited application, as the use of a phosphoric iron would not be practicable in such a case. The author further considers the question of the two processes, to the advantage of the Bertrand-Thiel process, which, he observes, possesses this advantage over the other steel-making processes, that it can be made to suit all conditions.

W. Schmidhammer,* discussing this criticism by Thiel on the joint Bessemer open-hearth process, observes, that in desiliconising in the converter it is not necessary to reduce the carbon to 0.1, and he quotes in proof of this the results of the preliminary experiments made at Witkowitz. The following is an analysis given:—

Converter:—	Per Cent.
Original silicon	1.31
Final silicon	trace
Final carbon	3.02
Open-hearth:—	
Final silicon . . . . .	...
Final carbon	0.12
Final phosphorus	0.03

with a five minutes blow in the converter before finishing in the open-hearth. Other results show silicon 0.05, 0.06, and a trace, and

* *Stahl und Eisen*, vol. xvii. p. 775.

the respective carbon percentages 1·54, 0·88, and 1·46, but these were for blows of from eight to fourteen minutes. The length of blow finally adopted was five minutes, as in the first case quoted.

H. G. Graves * briefly reviews some of the recent economies in iron and steel manufacture. Reference is made to Bonehill's direct puddling process, the Bertrand-Thiel open-hearth process, the Walrand process, the recovery of by-products and the utilisation of blast-furnace and basic slag.

J. Hartshorne † shows that there is an economy in time due to the use of the Bertrand-Thiel process, and also discusses the loss of iron, which is least when smaller amounts of scrap are used. It is not fair to charge to the loss the iron introduced as ore.

Open-Hearths at the Duisburg Steelworks.—According to C. Caspersson,‡ there are two open-hearths at this works, and these are provided with cylindrical gas-producers. They are lined with dolomite, the bottoms being stamped in the usual way. At the back are four layers of dolomite bricks. Outside these, and between them and the outer thin wall of acid bricks next the plate, is stamped in the ordinary dolomite material. Magnesite is used between the acid roof and the dolomite lining. Similar details are given as to the other parts of the furnace. The dolomite bricks are stamped out of a tar-dolomite mass in iron moulds, and are burnt in a kiln two yards in length, in which are placed four rows of fifty bricks each. The kiln is fired with coal. Six hours after firing the tar in the bricks begins to burn. The coal firing then ceases, and the tar is allowed to burn itself out, which it does in the course of three hours. The bricks are then allowed to cool down slowly. The dolomite is calcined with the aid of coke in a cupola lined at the bottom with acid bricks, and above with dolomite. The method of starting a newly repaired furnace is described, and also the use of the furnace generally. Körting injectors are used in driving the producers. From pig iron containing 0·2 to 1·0 per cent. of phosphorus, iron of excellent quality is stated to be made. The tapping is done with conical moulds connected with one another, with the wide end at the bottom. Ingots of very good quality result. The roof of a furnace usually lasts seven or eight weeks, and the bottom three-and-a-half to four months. The regenerator chambers

* *The Mineral Industry*, vol. v. pp. 377-381.

† *American Manufacturer*, vol. lx. pp. 368-369.

‡ *Jernkontorets Annaler*, vol. li. pp. 319-327.

are also usually cleaned and put in order every three-and-a-half to four months, and the pipe-ways are cleaned out every seven weeks. Once a day the producers are freed from slag.

The Use of Aluminium in Open-Hearth Steel.—According to A. E. Hunt,* the proportion of aluminium added in the manufacture of open-hearth steel ingots is two to four, or at most five ounces per ton. The metal is added in the ladle, generally as the steel is being cast into the moulds. Bessemer steel requires one to three ounces per ton more than open-hearth steel, and if the steel is wild, larger quantities are added. Its chief advantage is that it increases the soundness of the tops of ingots, and so diminishes the loss in scrap. Ebullition is quieted, and the metal solidifies more quickly without rising in the mould. If too much is used, however, there is a tendency to pipe, but in ordinary castings this is immaterial if a sufficient shrinkage head is provided. Aluminium rapidly and uniformly permeates the metal. It does not harden the metal, and there are no varieties of steel made containing large quantities, as is the case with chrome or tungsten steel. It acts as a deoxidising agent, ranking next to silicon in some respects, but it combines more thoroughly with the oxygen present, and does not linger in the steel as silicon does. Generally the metal itself is used as the addition, but sometimes recourse is had to ferro-aluminium containing 5, 10, or even 20 per cent. of aluminium, and placed in the ladle before tapping the furnace. The tensile strength of steel is increased without decreasing the ductility. Smoother castings are made, and there is less liability to oxidation during casting. Reference is also made to Mitis castings and to the use of aluminium in cast iron. For the latter purpose no great advantage is obtained. It changes combined carbon to graphite, reduces the tendency to chill, and slightly increases the strength.

Charging Open-Hearth Furnaces.—The method of charging open-hearth furnaces by the aid of mechanical appliances is discussed editorially in *Stahl und Eisen*,† the paper on this subject by Jeremiah Head ‡ being largely drawn on. Five Wellman charging machines are in use in Germany and one in Russia. It gives every satisfaction.

* *Journal of the Franklin Institute*, vol. cxliv. pp. 81-112, 171-198; *Aluminium World*, vol. iii. pp. 182-183.

† Vol. xvii. pp. 708-715; ten illustrations.

‡ *Journal of the Iron and Steel Institute*, 1897, No. I. p. 89.

The Lentz* charging crane is described and illustrated. This is stated to be in use at several works. Most open-hearth plants, it is pointed out, have too little free space behind the furnaces to enable any of the various charging appliances to which attention has of late been directed to be used without a costly reconstruction of the plant. The charging crane now described is worked by electricity. It runs on rails, and its various movements are controlled by five motors. It is stated to be extremely mobile, and to possess various advantages, to which attention is directed.

A plan and elevations of the open-hearth plant at the Homestead Works, Pittsburgh, has been published† to show the arrangements for handling and storing material. The Wellman charging machine and boxes are used. Storage space is provided in the form of bins on either side of the open-hearth buildings, and each of these is commanded by two overhead travelling electric five-ton cranes. These have a hoisting speed of 50 feet, a trolley speed of 150 feet, and a travelling speed of 600 feet per minute. The span and length of run on one side are 48 feet 7 inches and 490 feet respectively, and on the other side 52 feet and 630 feet. In both cases the cranes command the railway truck lines, the bins and the box tram lines, so that stock can be transferred direct from the trucks or bins into the charging boxes.

Steelworks.—Illustrated descriptions have been published of the Dowlais Cardiff Iron and Steel Works,‡ and of the Sandvik Steelworks§ in Sweden. F. Hilton|| describes the works of the Bethlehem Iron Company and other American steelworks.

An illustrated description has been published¶ of the works of Vickers, Sons & Co., Limited, at Sheffield.

A lengthy description and a plan of the Holtzer Steel Works at Unieux have also been published.**

Open-Hearth Steel in Alabama.—P. G. Shook†† deals with the manufacture of steel in the Birmingham district, Alabama, in reference

* *Stahl und Eisen*, vol. xvii. pp. 857-852; three illustrations.

† *Iron Age*, vol. ix. No. 7, pp. 8-9.

‡ *Iron and Coal Trades Review*, vol. liv. pp. 753-757.

§ *Ibid.*, vol. lv. pp. 309-310.

|| *Ibid.*, vol. lv. pp. 571-573, 609-610.

¶ *Engineering*, vol. lxiv. pp. 403, 430, 521.

** *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1897, pp. 97-105.

†† *Proceedings of the Alabama Industrial and Scientific Society*, vol. vi. pp. 24-41.

to the low cost of the pig iron and the great adaptability of the basic open-hearth process. Scrap is not absolutely necessary as the so-called "wash-metal," or molten pig iron run through a bath of basic slag may be used. A record of one heat made with Birmingham basic iron is as follows:—

	lbs.
91 per cent. Alabama pig iron	40,000
9 per cent. crop ends from blooming-mill	4,000
Hæmatite with charge	4,000
Limestone with charge	4,400
Hæmatite as additions	2,900
Burnt lime as additions	750
Final addition	250

Ingots produced weighed 42,400 lbs., and scrap 925 lbs. The time from charging to tapping was eleven hours fifty-five minutes. Tests showed an elastic limit of 35,150 lbs., tensile strength, 51,450 lbs., reduction of area, 64 per cent., elongation on 8 inches, $31\frac{1}{2}$ per cent. Analyses showed as follows:—

	Si.	C.	P.	S.	Mn.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Pig iron	0.52	...	0.72	0.02	...
Scrap . . . . .	...	0.10	0.60	0.060	0.35
Steel . . . . .	...	0.11	0.016	0.037	0.30

The cost of production is also discussed.

An epoch in the iron trade of the Southern United States has been marked by the successful start of the first basic open-hearth steel furnace of the Birmingham Rolling Mill Company at Birmingham, Alabama.*

III.—THE BESSEMER PROCESS.

The Invention of the Bessemer Process.—It had been the intention of J. D. Weeks to have considerably modified his presidential address, which dealt with the invention of the Bessemer process, but this was prevented by his death. A sketch of this address only has therefore been published, and this has been modified in accordance with his wishes. It shows how priority in the application of the pneumatic principle may be ascribed to W. Kelly, but it leaves the indepen-

* *Iron Age*, vol. lx. No. 5, p. 18.

dent discovery of this basal point to Sir Henry Bessemer, and ascribes to him the full credit for its successful mechanical application. Some of the appendices, which contain the discussion and are of historical value, are also given.*

In a paper read before the Verein Deutscher Eisenhüttenleute, it is pointed out by Malz † that the recognition of the great value of the Bessemer process was not long delayed after its discovery. He refers to the preliminary difficulties that were experienced when the process was introduced into practice. The progress in the improvement in the quality of the metal produced was accompanied by improvement in the plant used. The original system of arrangement of a Bessemer plant is mentioned, and the author observes that scarcely any important alteration in this has taken place. In the case of the Bessemer process as practised in the United States, it is characterised by the rapid way in which one blow follows another, and the low percentage of silicon in the pig iron blown. At some works this falls frequently below 1 per cent., and enables the blow to be completed in from eight to fourteen minutes. The pig iron has the following average percentage composition :—

Carbon.	Manganese.	Phosphorus.	Sulphur.	Silicon.
3·3 to 3·7	0·5 to 1·0	0·06 to 0·08	0·05 to 0·08	0·6 to 2·5

In rail steel works the converter usually is from 10 to 20 tons in capacity, and from 5 to 12 tons at works at which a soft metal is made. Other points with reference to American practice are referred to.

The Basic Process.—The basic process is discussed by Kintzlé ‡ in a paper read before the Verein Deutscher Eisenhüttenleute. Referring to Schrödter's statistical paper, the author points out that by far the greatest headway in regard to the basic process was made in Germany. This was largely connected with the question of the ore supplies. Over 90 per cent. of all the iron ore now being raised in Germany yields a pig iron which is not adapted for the acid Bessemer process, and two-thirds of the ore—that mined in Luxemburg and Lorraine, is suited only for the basic process.

After referring to the importance of the work done in the works' laboratory and testing department, the author considers the question

* *Transactions of the American Institute of Mining Engineers* (advance proof).

† *Stahl und Eisen*, vol. xvii. pp. 392-395.

‡ *Ibid.*, pp. 381-391; twelve illustrations.

of the rise and progress of the industry. At first some difficulty was experienced in connection with the durability of the basic linings used. To-day there is no difficulty in connection with this. Dolomites as pure as possible were selected, and the knowledge has been gained that this material should be burnt "sinter-hard," and used as fresh as possible; and further, the question of the importance of the good and even character of the tar used having been understood, all this led to important progress in the above direction. The use of pressed unburnt bricks for the converter-linings is mentioned, and their size is referred to. The presses compress the raw material into these bricks under pressures of from 300 to 500 atmospheres. With an initial thickness of about $15\frac{3}{4}$ inches, a lining will stand from 170 to 200 blows when soft ingot iron is being made. When hard steel is being produced the lining does not last so well, as the blow is usually both hotter and longer continued. With regard to the converter bottom, the older method of stamping by hand around iron or wooden pins is still general. The Versen apparatus for this purpose is, however, likely to oust this older hand method. For the ton of ingots made, the general consumption of dolomite is from 66 to 77 lbs., and of tar from 5.5 to 6.6 lbs. The attempted use of natural or prepared magnesite has not led to any practical results. Converter bottoms, the author observes, will stand from twenty-five to forty blows according to the varying conditions. In the earlier years of the basic process all the pig iron used was remelted in the cupola, but subsequently the use of direct metal became more and more common. At first only the ladle was used, but subsequently the mixer was introduced as well. To-day all these three methods are in use. Comparing the three, the author observes that each one has both its advantages and its disadvantages. The cupola method enables the steelworks to be independent of the blast-furnace plant as regards supply of material and the character of the metal, which can be mixed at will. This process approaches the most closely to the "mixer" process. The cupola method, however, is not a cheap one, and it is the great desire of every one using this method to reduce such costs as much as possible. This has led to the use of larger and better cupolas, higher pressure, more tuyeres, mechanical charging arrangements, &c. This has now resulted in cupolas being used which resemble in size small blast-furnaces, yielding 30 to 40 tons of molten iron per hour, with a coke consumption amounting to from 6 to 7 per cent. of the weight of iron charged, and with a blast pressure of 47 to 65 inches of water.

Discussing the use of mixers, the author refers to the separation of sulphur in these. At each plant there are usually two each of 100 to 150 tons capacity. The charging is effected either by means of an engine and an inclined plane, or else indirectly by means of a hoist of some sort. In tabular form is given the results of a large number of partial analyses of samples from such a mixer, as well as of the iron charged into it, showing clearly the averaging character of the mixer when charged with iron of very varying composition. The action of the manganese in eliminating sulphur is clearly indicated in these. Another very interesting point shown is the extent to which sulphur is eliminated in the ladle used to convey the iron from the blast-furnace to the mixer. About one-half the total quantity was thus eliminated. The following are a few of the analyses showing the elimination :—

At the Blast-Furnace.		When Charged into the Mixer.	
Manganese.	Sulphur.	Manganese.	Sulphur.
Per Cent.	Per Cent.	Per Cent.	Per Cent.
1·03	0·19	0·85	0·10
1·13	0·20	0·86	0·10
1·03	0·25	0·70	0·14
1·13	0·22	0·80	0·07
1·31	0·20	1·17	0·08
0·75	0·19	0·56	0·14
0·75	0·22	0·51	0·16
0·99	0·24	0·75	0·14
1·60	0·18	0·84	0·06
1·55	0·15	0·99	0·08

The following are similar partial analyses of this metal as poured into the converter after passing through the mixer :—

Manganese.	Sulphur.
Per Cent.	Per Cent.
0·90	0·04
0·84	0·04
0·75	0·07
0·80	0·06
0·71	0·06
0·67	0·09
0·61	0·10
0·71	0·08
0·71	0·07
0·84	0·06
0·75	0·09
0·80	0·07

The author considers that in many cases the bad quality of a piece of metal is very wrongly attributed to the sulphur present. He has himself introduced as much as 0.3 per cent. of sulphur into an iron containing 0.5 per cent. of manganese without any particular influence on the quality of the metal. The bad qualities observed may be really due to the presence of iron oxide. A similar remark may be made in connection with the presence of copper. Up to 0.2 or 0.3 per cent. of this may be in the metal without any bad result. Just as in the case of sulphur, so too with copper, the simultaneous presence of manganese plays an important part. The author consequently thinks that misleading deductions may result from an inspection of partial chemical analysis. The cost of a mixer is very slight, and could scarcely exceed about a penny to twopence per ton.

Dealing next with the lime used in the basic process, the author points out that it was quite early noticed that it should be as fresh as possible when used. The quantity used must of course depend on the percentages of silicon and sulphur present, and an excess of from 3 to 8 per cent. must be employed. The charging of the lime at different portions of the blow and the removal of the slag has been frequently proposed and tried in practice, but is now generally abandoned. The author refers to the improvements that have been introduced in connection with the shape and increasing size of the converter used. In present practice, it may be considered that a blow lasts on the average one minute per ton of ingots made. The metal charged has in many places risen to from 12 to 15 tons. The loss of metal varies from 13 to 16 per cent., 8 or 9 per cent. of this being due to the silicon, manganese, phosphorus, carbon, and sulphur eliminated from the metal. The remainder is due to loss of iron. Now, as formerly, only small quantities of silicon are allowed to be in the pig iron, from 0.3 to 0.7 per cent. being about the limits. The same is the case for sulphur, which never exceeds in the converter 0.10 per cent. The phosphorus is kept between the limits 1.7 and 2.2 per cent. With regard to the part played by the manganese, the views held are still very diverse. Many indeed work with 1 per cent. or less in the converter, whilst others insist on 1.6 or 1.8 per cent., and even more. The author himself considers this element as most important, and considers that an adequate percentage should be present.

With regard to the pouring of the ingots on the Saar, in Luxemburg, and in the north of France, the round casting pit with central crane has been completely adhered to. Usually two converters are served

by one central crane, but others make one such central crane serve for three converters. In Westphalia and in the Rhenish province, the system of a movable crane is generally adopted. Large ingots are usually poured from above, smaller ones often from below, and in groups of twenty or thirty or more. The weight of the ingots varies from $1\frac{1}{2}$ ton to 3 tons and upwards. Heated and unheated soaking pits are in use.

The question of the removal of the slag is next dealt with, and the Darby process is also mentioned, as too are the use of ferro-silicon and ferro-aluminium. The subsequent use and treatment of the basic slag is next dealt with. Ball-mills for grinding it are in general use. They are extremely simple and perfectly dust free. At least 75 per cent. of the ground material will pass through a sieve of 900 meshes per square centimetre. A number of illustrations are given, and these include sketch plans of basic Bessemer works.

New German Steelworks Plant.—At Lichtentanne, near Zwickau, a new steelworks plant is to be erected. This, according to Schiffner,* will remelt the pig iron in cupolas, and then convert it into steel in a basic-lined converter. The ingots will be treated in soaking-pits, and then rolled into rolls, beams, &c. The works will also include a basic brick plant, plant for grinding the basic slag, machine-shops, boiler plant, &c.

Basic Slag.—W. Borchers † discusses a process for obtaining phosphorus and calcium carbide from basic slag. Tricalcium phosphate is mixed with an excess of powdered carbon, and heated in an electric furnace. Calcium carbide, phosphorus, and carbonic oxide are formed. The phosphorus is recovered in a condenser, the yield being stated to be 80 per cent. of that theoretically possible. A series of experiments were made by the author with a view of converting the phosphates of these slags into phosphides, the latter to serve as a deoxidising material for overblown iron. The results, however, proved negative, the lime in the slag giving off its phosphorus and forming calcium carbide.

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. p. 410.

† *Zeitschrift für Elektrochemie*, June 20, 1897.

FURTHER TREATMENT OF IRON AND STEEL.

Centrifugal Teeming.—A method of centrifugal casting has been introduced by P. Huth.* Castings similar to the ordinary chilled castings he prepares in the following way. The mould is caused to rotate, and then hard steel is poured in. This flies to the sides, and soft steel is afterwards poured into the hollow centre. The casting produced has therefore a soft core and a hard face. Although both metals are intimately combined, yet the limits between them are readily recognisable. A number of applications are given, such as waggon wheels with hard rims, gear wheels with hard teeth, projectiles with hard points, jaws for rock-crushers, stamp dies with hard faces, armour plate, plough points, hard surface rolls of all kinds, hard-faced rails made of a cast ring cut open and rolled, &c.

New Casting Ladle.—Illustrations are published † of an arrangement consisting of a locomotive attached by a universal coupling to a carriage to which is attached a casting ladle on a hydraulic crane. It is served by two men.

Annealing Furnaces.—Illustrations have appeared ‡ of an annealing furnace, designed by S. A. Sague, for annealing tubes and wire. The furnace is of the reverberatory type, with a bed 13 feet broad, and a charging door at the end farthest from the fire. The fire-bridge is extended forward as a horizontal partition to cover a rolley way by which the work is withdrawn. The articles, such as bicycle tubes in 12-foot lengths, are contained in closed cylinders, which roll over as they are pushed towards the fire-bridge on the introduction of a cold cylinder, and thus get heated equally.

* *Stahl und Eisen*, vol. xvii. pp. 572-573; two illustrations.

† *Ibid.*, pp. 569-570; two illustrations.

‡ *Iron Trade Review*, vol. xxx. No. 27, pp. 14-15.

Illustrations have appeared * of an appliance, devised by F. I. Freeman, for charging reheating or annealing furnaces. Rails are laid in grooves in the furnace bed and in the floor in front of the charging door, where the pots, &c., are placed. A trolley is run under them, having an arrangement of wedges and screws, whereby its upper surface can be lifted or lowered to pick up or deposit the pots.

Wrought Iron in Machine Construction.—It is pointed out by Knoke† that in machine construction wrought iron is in many cases very difficult to replace, and ingot metal so far has not been able to take its place for every purpose. Surfaces exposed to a rubbing action are required to be as hard as possible, while the metal below the surface is tough. Only weld iron was formerly used for this purpose, but considerable time was required to harden the surface. Now-a-days it is very easy to do this relatively rapidly if ingot iron is employed; but the results are less satisfactory, the degree of hardening that results being very irregular.

Nickel-Steel Crank-Shaft.—Illustrations are published of the crank shaft for the new steamer *Kaiser Wilhelm der Grosse*, for the North German Lloyd line. This has been manufactured at the works of Messrs. Krupp of Essen. The material has a tensile strength of 39·4 tons per square inch, with an elongation of 20 per cent. It has a total weight of 83·3 metric tons. It is 45 feet 9½ inches in length. Similar nickel-steel crank-shafts, though of smaller size, have been made for other steamers.‡

As showing the progress made in the construction of steel ships in recent years in Germany, the recent launch of the *Kaiser Wilhelm der Grosse* by the Vulcan Company of Bredow, near Stettin, is of interest. This vessel is the largest afloat, and has a displacement of 20,500 tons, with engines of 27,000 horse-power. She was expected to have a speed of twenty-one knots, and in her first voyage to the United States has succeeded in breaking the record for the passage.§

Railway Axles.—R. A. Mould|| compares the use of iron and steel for railway axles, and states that on one line the total number of

* *Iron Trade Review*, vol. xxx. No. 29, pp. 12-14.

† *Stahl und Eisen*, vol. xvii. p. 518.

‡ *Ibid.*, pp. 484-485; two illustrations.

§ *Western Evening Herald*, September 27, 1897.

|| Paper read before the National Railway Master Blacksmiths' Association, through the *Iron Trade Review*, vol. xxx. No. 37, p. 14.

failures has been fifty-seven iron axles and fourteen steel axles. The homogeneity of the metal in steel axles is greatly in their favour. A number of tests of wearing capacity of various kinds of axles show the advantage of steel.

A photographic illustration of a mill for rolling axles has recently appeared.* The axle is passed between a large roll and a circular die plate, which approaches more closely to the roll where the axle emerges at the bottom. The roll is 48 inches in diameter and 98 inches in length. An 800 horse-power engine drives the machine.

Dressing-Wheels and Axles.—R. Atkinson † describes the Sibbald machine used for dressing railway wheels and axles, and the results produced by it. In this machine a steel disc about 33 inches in diameter, and containing about 0.65 per cent. of carbon, is given a peripheral velocity of about 33,000 feet per minute. It is pressed against the wheel, &c., which is slowly revolved, and the frictional resistance is converted into heat. The disc cuts or rubs off the heated metal, leaving a smooth hard surface varying from $\frac{1}{16}$ to $\frac{1}{100}$ inch deep. The efficiency is greatly increased by passing an electric current between the disc and the work, to generate additional heat at the point of contact. The current appears to increase the co-efficient of friction, and therefore to reduce the pressure necessary. With the expenditure of about 100 to 120 horse-power, $2\frac{1}{4}$ to 3 lbs. of metal are removed per minute. The consumption of current amounts to two electrical horse-power.

Weldless Chains.—An illustrated description has been published ‡ of the process invented by O. Klatte for the manufacture of rolled weldless steel chain cable.

Modern Steel Bridges.—A general consideration of recent suspension-bridges is published by Mehrrens.§ At the present time, he points out, there is in the whole world but one suspension-bridge used for the traffic of main lines of railway. This is the bridge over Niagara, built in 1851–55. But even this bridge, although it has since been considerably strengthened, no longer affords the necessary degree of safety for heavy traffic, and is to be replaced by an ordinary iron bridge. It was

* *Iron Trade Review*, vol. xxx. No. 34, p. 11.

† *Transactions of the Canadian Society of Civil Engineers*, vol. x. pp. 189–207, with illustration.

‡ *The Shipping World*, vol. xvii. pp. 443–446.

§ *Stahl und Eisen*, vol. xvii. pp. 495–505 with ; thirteen illustrations.

probably the construction of the Britannia Bridge by Stephenson that led to suspension-bridges not being adopted in the case of wide spans in railway construction. Even in the United States, where suspension-bridges have been adopted on the largest scale, ordinary bridges soon took precedence of their rivals. In the last twenty years, however, both in Europe as well as in the United States, attention has again been prominently directed to suspension-bridge construction. They were formerly not "stiff" enough, but this difficulty has now been met, while other points in which they showed themselves unsatisfactory have also been overcome, and the belief has gradually become more and more general that suspension-bridges for very wide spans are the most satisfactory. It is certain that wire is the best material for the most important parts of such wide-span bridges. The manufacture of a hard and tough wire has of late achieved such a degree of success that, in future, wire having the tensile strength of 76 to 95 tons per square inch will be available for use, with a permissible tension of 25 to 32 tons. It was the elder R bbling that introduced the use of cast steel wire into suspension-bridge construction, and the Brooklyn Bridge, with a central span of 1600 feet, is thus far the largest reached. Great difficulties were experienced in placing the cables in position, and the author refers to the proposals that were subsequently made to overcome them. The author also shows that a chain of wire links would not be preferable to a wire rope. It could not be made strong enough except it had an excessive weight. Thus, for a span of less than 1000 feet, under ordinary conditions a chain would weigh about three times as much as a wire cable of adequate strength. The author thinks that the most perfect cable is one composed of a large number of thin wires of equal length, and running in the same direction. If properly wound, bound, and protected, a rusting of the wires need not be feared, and the author fails to see any advantage in this connection that is possessed by any other form of construction of sheet or plate metal. He next proceeds to consider in detail the suspension-bridges recently proposed or constructed.

A series of iron bridges recently erected in Germany are described by Foerster.* The first illustration shows the M ngsten Bridge during the process of construction. This spans the M ngsten valley, between Remscheid and Solingen. It has a main span of 560 feet, and forms, with the bridges over the Garabit valley, near Saint-Flour, and the Luiz I. Bridge over the Douro at Oporto, the widest valley bridges in

* *Stahl und Eisen*, vol. xvii. pp. 752-761, with twelve illustrations.

Europe. All these are illustrated. Dealing next with new bridges over the Rhine, the author illustrates four—one at Bonn, two at Worms, and one at Düsseldorf. That at Bonn has the widest span. This amounts to about 643 feet.

The Müngsten Bridge has a total length of 1533 feet. Basic steel has been used in its construction, and the total weight of the metal-work of the bridge amounts to 5100 tons. In addition, some 13,000 cubic yards of masonry have also been employed in the construction of this bridge, the total cost of which has been £137,500. The Bonn and Worms bridges are described in detail, and information is also given as to others.

In his concluding remarks, the author points out that Germany, although at first it made but slow progress in bridge construction, has now left the United Kingdom and France behind, and has attained a position that even the United States can scarcely rival. Details are given by the author as to the dimensions of the different bridges and the weights of the ironwork, &c., used, but no analyses or tests are given of the metal.

The subject is further discussed by Mehrrens.* He deals with the proposals submitted for a bridge across the Danube at Budapest, and another at Bonn. Illustrations are also shown of a suspension-bridge near Langenargen, on the Lake of Constance. The question of the way in which the cables are arranged is considered, and the subject is dealt with generally.

Electric Furnaces.—H. Moissan † has published a monograph on the electric furnace. His researches on the transformation of carbon, the preparation of elements, the formation of carbides, borides, and silicides, are fully dealt with.

A useful treatise on the electric furnace has also been published by W. Borchers.‡ This type of furnace is gradually coming into use for many purposes, and the author describes its construction and the method of working it. The temperatures which are obtainable in this type of furnace being exceptionally high, its use is likely to spread considerably.

Heibling, § in the course of some experiments with the electric

* *Stahl und Eisen*, vol. xvii. pp. 868-873; nine illustrations.

† *La Four Electrique*, large 8vo, pp. 385. Paris: G. Steinheil, 1897.

‡ Vol. ix. of the *Encyklopädie der Elektrochemie*. Halle, 1897, pp. 64, three shillings.

§ *Génie Civil*, vol. xxx. pp. 333-334.

furnace, treated chrome iron ore from Boucau, in the Basses Pyrenees. By using lime and carbon as flux, ferrochrome in ingots was obtained, and the residue could be used as calcium carbide for the production of acetylene.

Demetrio Helbig* has constructed an electric furnace which, while unable to provide the fierce heat of the Moissan furnace, has the advantage of furnishing a constant high temperature which may easily be maintained uniform over a larger area. The tubular furnace consists of a sheet-iron box closed at the ends by means of square diaphragms of compressed magnesia or other refractory substance. The diaphragms are perforated to permit the insertion of a carbon tube 20 inches long and 0.79 inch in diameter, with walls 0.2 inch thick. The ends are held by iron collars, to which the terminals of an electric circuit are clamped. On sending a current of 250 amperes at 40 volts through the carbon cylinder, it is heated to an intense white heat, and bodies inserted in the cylinder may be kept at a high and uniform temperature by regulating the current. A piece of Bayeux porcelain becomes as viscous as hot glass in six minutes. At first there is a slight difficulty, owing to the oxidation of the white-hot carbon by the oxygen of the air; but this is rapidly used up, and then the tube is surrounded by an atmosphere of nitrogen and carbonic acid. It might be advisable to keep the whole apparatus surrounded by an inert gas from the beginning.

An Electric Softening Machine.—J. Castner† refers to the use of the apparatus designed by the Thomson Electric Welding Company for reducing the hardness of the spots to be drilled in hardened armour plates, and for similar purposes. Inversely, if it is desired to harden a spot in the plate, this is effected by rapidly heating the particular portion of the metal in question and then at once withdrawing the source of heat. The hot spot being surrounded by a thick mass of cold metal, is so rapidly cooled that a hardening action results.

Armour Plate Manufacture.—A double hydraulic press for bending armour plates is illustrated.‡

Tin Plate Works.—A plan and illustrated description have been published§ of the Newcastle Steel and Tin Plate Company's Works,

* *Atti della R. Accademia dei Lincei*, vol. vi. pp. 314-320.

† *Stahl und Eisen*, vol. xvii. p. 323.

‡ *F* 7, vol. lxiv. pp. 135 and 140. § *Iron Age*, vol. lx. No. 4, pp. 7-9.

Newcastle, Pennsylvania. Bessemer steel billets are used. The south hot mill building contains six hot mills completed, two building and one three-high bar-mill run by two 750 horse-power Corliss engines. The cold mill contains twenty-one rolls driven by rope transmission from a single engine. In the north hot mill are twelve hot mills driven by rope transmission. There are two tinning houses containing altogether thirty-two tinning stacks.

According to a Foreign Office report by E. Law, the tin plate industry is being developed in Italy. The largest works is at Piombino, on the coast opposite the island of Elba, where there are six rolling-mills. With three mills the out-turn has amounted to eighty tons per week. The steel bars are imported, but works are being erected for making the bars from Elba iron. A small quantity of bars are received from a works near Genoa.

Illustrations have been published* of a vertical type of annealing furnace for tin plates. The chambers are made 44 inches in width, 38 inches deep, and long enough to hold three boxes. The furnace contains two chambers with flues leading through the partitions.

The Manufacture of Galvanised Iron.—The ordinary process of galvanising iron is to dip the sheet or other object after pickling into molten zinc. This has been improved by dipping first into molten lead, and the more recent modification is to use a bath divided by a longitudinal partition dipping into the metal. One side is covered by flaps of sheet iron, and in this side the zinc is contained. Owing to its lighter specific gravity, it floats on the melted lead which fills the remainder of the kettle, so that it is protected from excessive oxidation. The sheet is passed down through the lead and up through the zinc in the enclosed part.

Electrolytic methods of coating iron with zinc are then considered. In S. Wagner's method the work is connected to the negative pole, and a zinc electrode connected to the positive pole and covered with flannel saturated with zinc solution is moved over the surface to be coated. A flexible electrode is described for use with irregular forms. The Cowper-Coles method is used at Glasgow, and its application to pipes is described. The articles, after washing with soda to remove grease, are placed in a cage revolving slowly in a bath of sulphuric acid of 7.5 Baumé, or otherwise pickled, and are then thoroughly

* *Iron Trade Review*, vol. xxx. No. 27, p. 16.

washed. The pipes are then revolved in the electrolytic bath, anodes of zinc plates being used. The method of mounting the pipes and anodes in this bath are illustrated, but particulars are not given of the composition of the electrolyte.*

G. C. Reese† describes a new method of galvanising wire which has been proved practicable at a works at Darby, Pennsylvania. The ordinary method is to draw the wire through a bath and then through asbestos wipers, but the amount of metal to be kept liquid in order to heat up and coat the wire causes many difficulties. In the new method, the coils or bundles of wire are cleansed by acid and prepared in the usual manner to receive their coating. A whole bundle is then dipped into the bath of melted spelter, and when it has received a thorough coating it is removed and dropped into a centrifugal separator, which may be in motion for small light coils, or the machine may be started after heavy bundles are placed in it. After a short time the wire attains the same speed as the machine, and the surplus coating is almost instantly thrown off against the safety shield. The machine is then stopped and the bundle removed. This part of the process is performed as quickly as possible in order that none of the coating may solidify until after its removal from the machine. The wire is then subjected to an operation designed to prevent the strands from becoming welded together when such solidification takes place. This is accomplished by jarring the bundle on a block to keep the different strands in motion or separated from each other, or by unwinding the bundle and re-winding it in such a manner that the coating may solidify while in transit from the unwinding to the re-winding reels. Barbed wire and other work may also be treated in this way.

The Manufacture of Steel Barrels.—A plant has been erected at Uxbridge for the manufacture of steel barrels. The body is made by convexed rolls from sheet steel $\frac{1}{8}$ inch and upwards in thickness, and the joint is made by melting on a steel strip by the Bernardos process, and finished by hammering. The ends are stamped with flanges and corrugations, and put on with hoops which are also welded on by the same process.‡

* *Génie Civil*, vol. xxxi. pp. 38-40.

† *Journal of the Franklin Institute*, vol. cxliv. pp. 312-318.

‡ *The Engineer*, vol. lxxxiv. p. 83, with illustrations.

Oil-Gas Furnace.—A. Victorin* recommends the use of oil-gas fuel, and describes a vertical furnace for heating the shells to be shrunk on guns. It consists of a vertical cylinder with burners arranged tangentially.

Smiths' Fires.—Haedicke † describes a series of experiments made with smiths' fires, with and without the use of finely-divided water injected with the blast. He first describes ordinary smiths' fires, both with side and bottom blast, and then refers to the character of the fuel burnt in them, showing the advantage that is to be derived from the use of small coke. What is known by the name of small coke in Germany is coke which will pass through a sieve having a 0·8-inch mesh, but not through a sieve having a 0·48-inch mesh. The author observes that although such small coke has long been in use in the United Kingdom, it is still only but very little employed in Germany. With a view to ascertain the relative results obtainable in these different systems of firing and with different fuels, comparative experiments were made at Remscheid. The experiments involved the heating to a good red of as many pieces of iron rod, 0·8 inch in diameter and 4 inches in length, as could be heated properly with the quantities of fuel used. The temperature reached in each case was determined not by eye, but by plunging into a known weight of water, and observing the rise of temperature. The results are tabulated, and were as follows :—

Fuel and Method of Heating.	Weight of Fuel used per Kilog. Iron.	Fuel utilised per Cent. of Possible Calories.
Side blast, coal	1·320	1·660
Bottom blast, coal	0·808	2·745
A "coke" hearth, but coal used	0·845	2·620
The same with coke	0·501	4·140
" " " " " " " " " " " " " " " " " "	0·520	4·210
Coke and water-spray	0·434	4·790
" " " " " " " " " " " " " " " " " "	0·384	5·400
Coal and water-spray	0·639	3·490
" " " " " " " " " " " " " " " " " "	0·697	3·200

Full details are given as to the results and the method of calculation, and in his final conclusion the author points out how valuable the use of the water-spray system of firing is where coal is used as fuel.

* *Report of the Chief of Ordnance*, 1896, pp. 141-144, with two plates.

† *Stahl und Eisen*, vol. xvii. pp. 761-765; five illustrations.

He observes that the results just referred to show the following as being the order of relative merit of the different systems of firing :—

1. Water-spray with coke.
2. Coke fire.
3. Coal fire with bottom blast.
4. "Coke" fire, but using coal.
5. Water-spray with coal.
6. Coal fire with side blast.

The latter represents the ordinary smith's fire. The action of the finely divided water is thought to be mechanical. It forces its way into the interior of the fuel, is vaporised, and splits the fuel up into finer particles, thereby facilitating their combustion.

PHYSICAL PROPERTIES.

The Micrographic Analysis of Metals.—J. O. Arnold* gives a sketch of the micrographic analysis of metals. After shortly describing the microscope and its accessories, the method used for preparing the samples is given in some detail. Various grades of emery, and then rouge on kid skin, is used for polishing, the sample being given a circular motion on the latter, and a right line motion on the former. For etching dilute nitric acid is used. Specimens are mounted in brass rings on glass slips under glass covers, Canada balsam being used. The nomenclature of the several constituents is given, and then a detailed account of the microscopic appearance of different samples of iron and steel, of which the physical properties are also generally given. Amongst these are Swedish Lancashire-hearth bar iron, steel castings, hard tool steel, mottled iron, and malleable iron.

Further parts of the elaborate and profusely illustrated paper by T. Andrews on microscopic observations on the deterioration by fatigue in steel rails have appeared.†

A. Sauveur‡ deals at length with the microscopical examination of iron and steel. He gives in detail the methods employed for grinding and polishing the specimens as used by himself and others. The quality of the abrading materials is discussed, and the supports to be used are described. For final polishing a hard support should be used, unless it is desired to polish in relief, when a flexible support is desirable. Polishing machines, as used by various observers, are also mentioned.

The Microstructure and Mechanical Properties of Steel.—N. N. Ljamin§ discusses the relations which exist between the micro-

* *The Mineral Industry*, vol. v. pp. 697-703.

† *Engineering*, vol. lxiii. p. 841, vol. lxiv. pp. 99, 249, 298, 455, &c.; *Journal of the Iron and Steel Institute*, 1897, No. I. p. 523.

‡ *Engineering and Mining Journal*, vol. lxiii. p. 662; vol. lxiv. pp. 69, 215.

§ *Zap. imp. russk. techn. obschtsch*, 1897; *Chemiker Zeitung*, vol. xxi., *Repertorium*, p. 205.

structure and the mechanical properties of steel. Investigations made by him show that the tensile strength increases with the percentage of perlite present, and with the increasing size of the granules of this substance, as has already been pointed out by Sauveur. In steel of comparatively low tensile strength, 38 to 41 tons per square inch, only black specks of perlite are observable on a white lustrous ground of ferrite. In harder steel, however, perlite is in excess. It occurs in polygonal granules, which are bordered, according to the degree of hardness of the metal, by ferrite in thicker or thinner sections. The reason why Sauveur's results were not altogether identical with those of the author was, he considers, because Sauveur was dealing with a material of too high a degree of uniformity. In etching the sections of the steel examined, the author used a bromine water solution of 2 per cent. strength. This was very rapid in its action, and gave very good results.

The Cellular Theory of Steel.—L. Baclé* continues his review of the cellular theory of steel. After briefly giving the results obtained by the earlier investigators, he summarises the views promulgated by Osmond, and then, in his third article on the subject, attention is turned to the practical application of the theory to working, annealing, hardening, and tempering. The metal is considered as being built up of cells cemented together. The cells become plastic at a temperature (*a*) somewhat above red, whilst the cementing material is unaffected until a higher temperature (*b*) is attained. The heating should be carried up to this temperature (*b*), and forging finished between that point and (*a*). If it finishes at a higher temperature, the metal shows a large grain and is brittle, but at lower temperatures it offers greater resistance to shocks. The difference of temperature throughout large masses explains the difficulties in working them. Annealing is necessary to render the grain uniform, and the heat should be carried up to or even a little over (*b*), both heating and then cooling rapidly down to (*a*), in order to liquefy and then solidify the cement around small-sized cells. This should be followed by slow cooling. The effect of hardening is complicated by many factors, Osmond giving no less than fourteen, and these are partly considered in the light of his researches, but further discussion on them and on tempering are promised.

* *Revue Universelle des Mines*, vol. xxxv. pp. 121-143, vol. xxxix. pp. 25-36; *Journal of the Iron and Steel Institute*, 1895, No. II. p. 542.

The Magnetic Properties of Iron and Steel.—K. E. Guthe * describes some experiments on the influence of heat treatment upon the magnetic properties of hardened steel. It is shown that the point at which steel becomes magnetically hardened by quenching lies at different temperatures, according to the amount of carbon contents. It is considerably lower in high carbon steel than in low carbon steel, and corresponds closely to the different temperatures at which occurs recalcence of steel. The higher above the point of recalcence steel is heated before being quenched the harder it is magnetically. The magnetic hardening produced by quenching is larger with higher percentages of carbon. Reheating has in general a softening effect upon the magnetic properties of hardened steel, *i.e.* the permeability increases, and is accompanied by an increase of maximum induction and a decrease of the coercive force. But a hardening is noticeable in the low carbon steel after it has been reheated for a short time to 100°. The greatest change in the maximum induction takes place for high carbon steel between 200° and 300°, for low carbon steel between 300° and 450°, beyond which temperature there is hardly any change in the practical limit of saturation. All change taking place in reheating beyond 450° consists in an increase of permeability for small magnetising forces, *i.e.* a decrease in the coercive force or hysteresis loss. To produce strong magnets the hardened steel should first be reheated to 450°. Heating to a high temperature below the point of recalcence and sudden quenching produces a steel with a very weak retentivity, in consequence of which the hysteresis loss in a cycle is greatly decreased. This result may also be obtained, though in a lesser degree, by annealing at a very high temperature.

J. Hopkinson † corrects some views previously expressed, recent experiments not confirming the opinion that heating iron above its critical point did not entirely destroy the effects of previous magnetism. The recalcence of pure iron is probably less than previously given by him.

E. T. Jones ‡ has attempted to determine whether the change of length which a nickel wire experiences when placed in a magnetic field can be explained by means of the stresses which are known to exist in consequence of the magnetisation. A contraction is always found, but the observed and calculated amounts differ considerably, the differ-

* Paper read before the American Institute of Electrical Engineers, through *Industries and Iron*, vol. xxii. pp. 354-374.

† *Proceedings of the Royal Society*, vol. lxi. p. 490.

‡ *Ibid.*, pp. 19-20.

ences being approximately proportional to the fourth power of the magnetisation.

R. van Tongel* observes that in view of electro-technical requirements, steelworks are now paying the greatest attention to the production of material of as high a magnetic permeability as possible. So far as experience has yet shown, soft steel possesses, as a rule, less resistance than hard steel. The mechanical treatment to which the metal is subjected has very great influence. The Joch method of testing is described, and it is pointed out that if accurate results are to be obtained the test-piece must first be carefully annealed and allowed to cool down very slowly. The author refers to the action of nickel, and observes that he is investigating the influence exerted by other added substances.

C. Heinke† further considers the magnetic properties of iron, and deals generally with the question, making use for the sake of simplicity of mechanical movements combined with friction, for the purpose of rendering the matter clearer.

E. Wilson‡ has experimented upon the magnetic properties of annealed wrought iron, manufactured from the iron sand of New Zealand. It is equal to best wrought iron as far as high induction density for high magnetising force is concerned, and slightly inferior to the best forged steel castings. Under low magnetising forces it is about normal. The results of tests are tabulated.

Experiments have been carried out by C. Chistoni and G. G. de Vecchi§ with a view of testing the alleged excellence of Valtrompia tungsten steel as regards permanence of magnetisation and high permeability. One specimen examined contained 6.25 per cent. of tungsten, 0.99 per cent. carbon, 1 per cent. manganese, 0.19 per cent. silicon, and the rest iron. Another specimen contained 4.15 per cent. tungsten, and somewhat less manganese and more carbon. Comparing their magnetisations in various fields with those obtained by Barus and Strouhal, they are certainly superior to the latter. The specific magnetic moment quoted by these authors as the maximum is 23.5, whereas the maxima obtained from the Valtrompia specimens were 47.6 and 55.6.

The material most commonly used for the cores of electro-magnets is

* *Chemiker Zeitung*, vol. xxi. p. 586.

† *Stahl und Eisen*, vol. xvii. pp. 295-301; five illustrations.

‡ *Electrician*, vol. xxxix. pp. 672-673.

§ *Nuovo Cimento*, September 1897; *Electrician*, vol. xl. p. 36.

soft iron, on account of its high permeability. But soft open-hearth steel is often quite as effective, and is more easily obtained. It may be used wherever a rapid change of magnetisation is not essential. A comparison, undertaken by A. Abt,* between two exactly similar horse-shoe cores of soft steel and soft iron, gave 0.98 to 1.04 for the ratio of the permeabilities of the former to the latter, and 1.2 to 1.3 as the ratio of the permanent magnetisms. This places soft steel very close to soft iron in magnetic behaviour.

H. Wilde † describes some recent experiments on the magnetisation limit of iron. A single pole electro-magnet is used, and the force required to draw away a short length of iron wire is measured. Previous experiments appeared to indicate a limit of 400 lbs. per square inch, but this is now increased to a practically determined amount of 422 lbs.

J. A. Fleming ‡ describes a method of determining magnetic hysteresis loss in straight iron strips. The samples of iron, large or small, in the form of straight strips, are inserted in a long solenoid traversed by an alternating current, and the square-roots of the mean square values of the current are determined by a Kelvin balance and an exploring coil. It is shown that if the secondary coil is placed at a spot 0.22 of the whole length from one end, and the secondary voltage then observed is used to calculate the induction density, the value so obtained corresponds to the true mean value of the varying hysteresis loss per cubic centimetre all along the strip.

A. Ebeling § and E. Schmidt deal with the magnetic properties of various varieties of iron and steel and with the Steinmetz coefficient for magnetic hysteresis. They show that steel castings of high magnetic quality are now produced by steelworks, and they give a series of results relating to bar iron, and ingot iron, and steel castings. Materials for which the differences noted in the electro-conductivity are less than 1 per cent. are found to be also very homogeneous magnetically. The greatest difference of this kind observed was in the case of a wrought iron bar, in which differences of as much as 15 per cent. were noted, and this bar was found to be magnetically very wanting in homogeneity. Samples taken from the middle portion of a plate and from its sides often showed great difference in their magnetic proper-

* *Wiedemann's Annaler*, 1897, No. 8; *Electrician*, vol. xxxix. p. 535.

† *Proceedings of the Royal Society*, vol. lxi. pp. 291-293.

‡ Paper read before the Physical Society; *Industries and Iron*, vol. xxii. p. 531.

§ *Stahl und Eisen*, vol. xvii. pp. 444-447.

ties. Annealing improves the quality of the metal magnetically, and some steel castings reach a degree of magnetic "softness" which is very little behind that of the best varieties of weld iron.

The correspondence between the area of the magneto-metric hysteresis curves and the heat actually developed in a sample of iron subjected to alternate magnetisation is not yet settled. Warburg found the actual heat 68 per cent. ; Tanakadate, 80 per cent. ; and Klemencie, over 100 per cent. of the theoretical heat. F. A. Weihe* has now tackled the question by a new method. The magnetising coil did not surround the samples direct, but was divided from them by a cylinder of ice. The samples, consisting of bundles of insulated iron and steel wires, were themselves surrounded by a separate cylinder of calorimeter ice. The frequency of the current from the dynamo was 55 per second, and the induction about 200. The results agree with the Japanese observations, giving 80 per cent. for iron and 73 per cent. for steel.

J. G. Leatham† has investigated the theory of the magneto-optic phenomena of iron, nickel, and cobalt. The magnetic field may affect the phenomena of light propagation in two ways, giving rise to two theories. The fundamental equation of the second of these are developed to obtain solutions of the problems of magnetic reflection and transmission through magnetised films. These formulæ are compared with experimental results and shown to be good.

The Hardening of Steel.—The paper by A. Sauveur‡ on the microstructure of steel and current theories of hardening has provoked a very large amount of discussion. Ledebur upholds the carbon theory, Scott tentatively advances the diamond theory again, and similarly Metcalf deals with the stress theory, Arnold strongly upholds his own theory, and the same is done by the supporters of the allotropic theory. It is impossible without enormously lengthening these abstracts to follow the discussion in detail, especially as it so often diverges into side issues and into purely polemical matters. Only a note is therefore given of some of the particular features brought forward by a few of those who have joined in the discussion, as it is felt that fresh papers will be published by the various parties

* *Electrician*, vol. xxxix. p. 472.

† *Proceedings of the Royal Society*, vol. lxi. pp. 487-490.

‡ *Transactions of the American Institute of Mining Engineers*. Discussion (advance proof).

within a short time, and that they will more completely summarise the scattered opinions of the several camps.

H. M. Howe* thinks that Sauveur in his paper on the micro-structure of steel and the current theory of hardening has presented a very impartial view of the subject. He also recapitulates the phenomena observed in connection with iron as—

1. The retardations in perfectly carbonless iron;
2. The hardening power of almost carbonless iron;
3. The loss of hardening power at the upper retardations without corresponding changes in carbon conditions;
4. The magnetic phenomena;

and he is of the opinion that all of these “seem in complete harmony with the allotropic theory. But on the carbon theory, the first is wholly inexplicable; the second and third are explicable only with difficulty; while as to the fourth, no explanation on this theory has yet been offered as far as he knows.” At the same time there are two chief considerations which lead to the view that the condition of carbon also plays a very important part in hardening. In certain steels much of the hardening power survives the upper retardations which mark the allotropic change, and is lost at about the lower retardation when the carbon changes its state. Still more important is the fact that manganese steel, although its magnetic properties show that it should mainly consist of β -iron, does not show the glass hardness and brittleness associated with high carbon steel. These may be explained on the allotropic theory, but the explanation is not altogether satisfactory.

Therefore it is thought probable that the strengthening of practically carbonless iron is due chiefly to allotropy, and that the hardening of low carbon steels in general is inconsiderable, and often in large part due to allotropy; and while it is inferred that allotropy also probably plays an important part in the hardening of high carbon steels, and while it seems the most reasonable explanation of the magnetic phenomena, yet the enormous increase in hardness obtained on suddenly cooling high carbon steel, and nowhere else, roughly proportional as it is to the carbon content, seems, especially in view of the relative softness of manganese steel, to raise a presumption in favour of the view that a special high temperature combination of iron and carbon contributes powerfully to the hardening of carbon

* *Transactions of the American Institute of Mining Engineers.* Discussion (advance proof).

steel in general, and especially is a very important cause of the two most striking effects of hardening, glass hardness and brittleness. Such views are provisional. It does not seem possible that the condition of the carbon should explain all the facts, but it is by no means improbable that further evidence may show that allotropy is the sole primary cause of hardening itself, *i.e.* of the change induced by sudden cooling. The two causes are not mutually exclusive, and the share of each must be sought for.

A. Ledebur* considers the subject of the different forms of carbon and the hardening of steel. He begins by a quotation from the fifth edition of the book on chemistry published in 1697 by Nicolas L'Emery:—"Iron is a very porous metal, consisting of vitriol, salt, sulphur, and earth." In 1557 Cardanus observed that steel "is nobler than iron, and is of two kinds, made and self-grown. . . . If it be well purified, and subsequently when red-hot plunged three or four times into radish juice and earth-worm water in equal parts, it cuts iron like lead." Other similar recipes for the hardening of steel were also given by him. Passing from these earlier treatises on the hardening of steel, the author proceeds to an enumeration of the articles on this subject which have appeared recently. It was not possible, he points out, for any theory to be developed properly until it had been observed that the carbon present in hardened steel is in a form different to that in which it exists in the unhardened metal, or, speaking more accurately, that that carbon which up to then had been considered as one single form, and had been named "combined," to distinguish it from graphite, was present really in two different forms, the relative percentage of which varied greatly in hardened and unhardened metal. Karsten in 1824 appears to have been the first to have observed this, but apparently at first little attention was paid to this discovery. The separation of a carbide by Abel in 1885 is next referred to. The experiments subsequently made to prove the exact composition of this carbide are next mentioned. Next are passed in review the observations as to temperature changes which occur when the changes in the state of the carbon result, and especially those made by Osmond and Howe. With regard to the allotropic theory, the author observes that if this is accepted in the case of iron, it must be accepted also for copper, bronze, and other metals and alloys. Mechanical treatment is able to bring about the same kind of difference in the physical properties of a metal as

* *Stahl und Eisen*, vol. xvii. pp. 436-439.

those which result from sudden cooling. The acceptance of the existence of two different forms of iron does not, however, of itself prove that the cause of the hardening is due to a delaying of the change of one form of iron into another, and that the carbon contents plays but a secondary part in the hardening process. The microscopic work that has been done and the discoveries this has effected are next passed in review, and Sauveur's work is especially mentioned. As Le Chatelier, too, has pointed out, in highly heated iron only martensite is present, ferrite and cementite disappearing the more completely the stronger the iron is heated. Quick cooling prevents the decomposition of the martensite. Sauveur's deductions are cited at great length.

The Influence of Sudden Cooling on Nearly Pure Iron.—

J. O. Arnold * comments on the experiments on this subject described by H. M. Howe,† and considers that they do not afford evidence for the allotropic theory. Some experiments are also described with iron containing :—

C.	Si.	Mn.	As.	P.	S.	Cu.	Al.
0·07	0·02	0·02	0·04	0·02	0·02	0·01	0·02

Round test-pieces 0·1 square inch area and 2 inches long were heated in nitrogen up to 990° C., allowed to cool to various temperatures, from which they were quenched in brine at an average of 5° C. The results of tests were as follows :—

Bar Number.	Quenching Temperature.	Maximum Stress.	Elongation.	Reduction of Area.
	Degrees Centigrade.	Tons per Square Inch.	Per Cent. in 2 Inches.	Per Cent.
Normal	15	21·42	44·0	80·0
3	400	21·59	43·0	76·8
6	525	22·46	41·0	78·8
8	600	23·02	34·0	76·2
2	650	25·56	31·5	76·8
5	705	26·24	27·5	73·8
11	780	29·79	29·5	70·8
4	820	29·46	27·5	75·4
9	887	32·63	21·5	75·9
1	928	31·35	30·5	76·2

Quenching below a red heat has little or no effect on the mechanical properties, but about 500° C. there is a well-marked critical point. The points Ar_2 and Ar_3 are without much effect. Between 500° and

* *Engineering and Mining Journal*, vol. lxiv. p. 213; *Engineering*, vol. lxiv. pp. 48-49.

† *Journal of the Iron and Steel Institute*, 1897, No. I. p. 525.

900° C. the increase in tenacity is proportional to the quenching temperature. Reduction of area is practically constant. This points to the conclusion that the increasing tenacity as the temperature of quenching rises is a measure of the crystalline stresses, internal and external. When these stresses are overwhelmed by the flow of the metal preceding rupture, the mass resumes its normal ductility as measured by the reduction of area. The elongation will obviously be largely governed by the rapidity of the localised rupture, which will determine the comparative percentages of elongation adjacent to and distant from the point of fracture.

H. M. Howe* in a note entitled "The Connection between the Hardening Power and the Retardation of Low Carbon Steel" fully acknowledges the value of these experiments, but maintains that the results support his own contentions and are not contrary to them, as Arnold thinks. An attempt is made to show that they are arguing at cross purposes, and that his own position and deductions are not fairly stated. Arnold's latest results are re-plotted, and it is shown that they should not be represented by a smooth curve, but by one with critical points corresponding to those in the temperature curve.

A. Sauveur† also comments on the above-quoted experiments of Arnold, and shows that instead of a steady rise in the tensile strength, when the metal is quenched, from between 500° and 900° C., there are marked increases at intervals which can only be referred to the effect of the three points Ar_1 , Ar_2 , Ar_3 .

J. O. Arnold‡ replies to Howe's criticism on the presentation of his results, and maintains his deductions, chiefly relying on the probabilities of experimental error as accounting for the variations.

Carbon Changes During the Annealing Process.—A. Ledebur§ in dealing with this subject, observes that until comparatively lately little was really known about annealing processes, and in particular about the preparation of malleable castings. Forquignon's experiments, published in 1886, on the annealing of iron in different substances were very valuable, and the author then deals in detail with the recent ones of Royston. While the author observes the use of the Le Chatelier pyrometer adds greatly to the value of such experiments, yet it is to be regretted that Royston still continues to distinguish only two forms of carbon—"graphite" and "combined." In the former he includes

* *Engineering and Mining Journal*, vol. lxiv. pp. 367-368. † *Ibid.*, pp. 489-490.

‡ *Engineering*, vol. lxiv. pp. 507-508. § *Stahl und Eisen*, vol. xvii. pp. 628-634.

temper carbon, and he fails to point out that the "combined" carbon includes two totally different carbon forms, and how each of these behaves on heating is not referred to.

The author next deals with other results obtained by Yoshitaro Watanabe in a series of experiments made at his own suggestion. These had for their chief aim to ascertain in what way the carbon changed on the iron being heated. The metal used in the tests was obtained from a works where malleable iron castings and tempered steel castings are made on a large scale. The test-pieces, before being heated, bore all the external appearance of ordinary white iron. In addition to carbon they contained the following constituents:—

Silicon.	Phosphorus.	Sulphur.	Manganese.
0.496	0.076	0.293	0.182

The percentage of silicon, phosphorus, and manganese underwent no very marked changes during the heating, but that of sulphur constantly increased as soon as the furnace was at its full heat, which temperature was reached on the third day after first firing. The following were the percentage results noted in the case of the sulphur:—

Original.	Fourth Day.	Fifth Day.	Sixth Day.	Seventh Day.	Eighth Day.
0.293	0.292	0.301	0.328	0.329	0.356

This enrichment in sulphur can only have resulted from its having been taken up from the material in which the metal was heated. After the firing had been continued for $8\frac{1}{2}$ days from first lighting up, the fire was drawn and the samples taken out. It was, unfortunately, impracticable to take temperature measurements during the progress of the experiment, but the temperature was a medium red heat. As these samples, like those of Royston, then consisted of a series of superimposed layers of different composition, holes were drilled right through them from side to side, and the samples obtained in this way were used for the analysis. The following were the results obtained:—

	Hardening Carbon.	Carbide Carbon.	Temper Carbon.	Total Carbon.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Before heating	0.741	2.597	...	3.338
Fourth day	0.815	2.246	...	3.061
Fifth day	0.859	2.073	...	2.932
Sixth day	0.835	1.874	0.179	2.888
Seventh day	0.631	0.430	1.037	2.098
Eighth day	0.245	0.492	0.833	1.570

As the percentage of carbon in the last sample was still very high, it was again strongly heated for two days, and it then contained :—

Hardening Carbon.	Carbide Carbon.	Temper Carbon.	Total Carbon.
...	0.656	0.443	1.099 *

It may seem strange at first, on examining the above results, to observe that the percentage of hardening carbon at first increases, and does not begin to diminish again until the sixth day. This may be explained as follows. In the red-hot metal all the carbon is present as hardening carbon, that is to say, it is dissolved in the iron. Only at the temperature of about 700° C., during the cooling, does carbide form, the quantity being the greater, the slower the cooling. The cast wheel from which the samples dealt with in these experiments were derived was cast in sand, and subjected to a gradual cooling in the mould. The percentage of carbide carbon in the original samples before heating is therefore somewhat high. The cooling down of the samples after these had been heated was more rapid, as they were taken out of the furnace when hot and allowed to cool down in air. They were also of much smaller weight than was the original casting, and consequently cooled more rapidly. In this way an explanation is obtained of the fact that the samples from the fourth, fifth, and sixth days were richer in hardening carbon than was the original sample. The heating-up of the furnace, and of the samples contained in it, was somewhat slow, and the change from carbide to hardening carbon could consequently proceed but slowly. The temperature of the samples in the furnace only attained its maximum about the sixth day.

Considering the subject generally, the author observes that, leaving theories out of consideration, certain facts may be considered as proved. If white pig iron low in manganese is heated for some time to a temperature of 850° or upwards, and is then allowed to cool down slowly below the hardening temperature—about 670°, that is—it will be found that a portion of the carbon it contains has been converted into temper carbon. The higher the temperature employed, the shorter need the period be during which it is continued. If it reaches nearly the melting-point of the metal, even a very temporary heating is adequate for the conversion of a portion of the carbon into temper carbon, and even a rapid cooling is unable in such a case to prevent the formation of considerable quantities of temper carbon. On the other hand, if a piece of iron containing a known percentage of temper carbon is raised to 920° or over, and then cooled rapidly, the percentage of temper carbon it

* 1.097 in original.

contains can in this way be diminished. These two facts appear in opposition to each other, and require further elucidation. Doubtless the results of these experiments were influenced by some secondary conditions which were not taken into account, provided there were no errors in the determinations themselves. When the percentage of total carbon in a specimen exceeds 0.9, it would appear that on heating temper carbon will form; but if the total percentage falls below 0.9, then, so far as is yet known, no temper carbon will form, even though the metal be subjected to a long-continued heating. Hammering red-hot iron appears to facilitate the formation of temper carbon. If white pig iron is heated under oxidising conditions, the presence of temper carbon may be observed in this case also, provided the metal is withdrawn before it is completely decarburised, and is not cooled down too rapidly. In such a fining process, as in other cases also, the percentage of temper carbon in the metal increases with the length of time the metal is under treatment and the degree of temperature to which it was exposed, but of course diminishes subsequently, as the percentage of total carbon also decreases.

Temper carbon differs from graphite by its solubility in red-hot but still solid metal. Whether temper carbon is a form of pure carbon, or whether it forms some constituent of a hitherto undetermined carbide not decomposable by acids, has not yet been with certainty determined.

The State of Combination of Carbon in Iron.—E. D. Campbell* thinks that much might be done towards determining the state in which iron and carbon are combined by proceeding on such lines of research as are adopted in organic chemistry and investigating the composition of the hydrocarbons evolved on solution in acids. Some of his preliminary investigations are described in the discussion of A. Sauveur's paper on the current theories of hardening. The carbide of iron is very generally described as Fe_3C , but very probably it may have a formula Fe_{3n}C_n . Pearlyte may be $\text{C}_n\text{Fe}_{3n}, \text{Fe}_{13n}$. Some of the experiments indicate that n may be 2, 3, 4, or 5 according to the kind of steel, and the indications are that there is more C_2Fe_6 in hardened than in annealed steel containing less than 1.3 per cent. of carbon. Probably above the point Ar_1 the ferroc carbons do not dissociate, but are dissolved in the steel, and perhaps at Ar_2 and Ar_3 there is a splitting up of the complex ferroc carbons. The author is disposed to think that many of the properties may be ascribed to the presence of these

* *Transactions of the American Institution of Mining Engineers.* Discussion (advance proof).

ferrocarbons or compounds of iron and carbon, which may be analogous in some respects to hydrocarbon, seeing that hydrogen often acts like a metal. Possibly the iron may also be in an allotropic state.

Influence of Low Temperature on Mechanical Properties.—

M. Rudeloff* publishes the results of further experiments, showing the effect of cold on the mechanical properties of weld iron and open-hearth and basic Bessemer ingot metals, the tests being performed both with the hammer and the press. They showed that cooling to -20°C . did not markedly affect the toughness of the weld iron, but the ingot metal had begun to become more brittle. Cooling to -80°C . caused both the weld iron and the ingot metal to become much more brittle. The basic Bessemer metal was somewhat more affected than the open-hearth metal. The bending capacity was reduced from 100 to 85 in the case of the open-hearth metal, and from 100 to 81 in that of the basic Bessemer steel. The influence of cold was less readily detectable in sound pieces of metal than in others which had been first nicked. Other results are also given. Crucible steel becomes very brittle at -80° , but a temperature of -20°C . is without much action. It was found that the results were similar when a falling weight was employed to those obtained when a press was used.

The Measurement of Very Low Temperatures.—For experimental purposes it is occasionally desirable to measure very low temperatures, and it is therefore interesting to note that it is possible to utilise for this purpose the contraction in volume of a mixture of hydrocarbon known as petroleum ether. By its use temperatures as low as -190°C . can be measured—that of boiling air. At -188° its volume is only four-fifths of that which it possesses at 0° , and three-fourths of that at $+30^{\circ}$. Electrical methods have been also employed with success for this purpose.†

The Expansion and Contraction of Iron.—G. E. Svedelius ‡ discusses the changes in length of iron and steel due to heating, and gives the results of experiments on this subject. Cold-drawn steel rods containing 0.9 to 0.1 per cent. of carbon, and hot-rolled steel rods with 1.0 to 0.1 per cent. were used. The expansions and contractions on heating and cooling were carefully measured by a mirror-lever appa-

* *Stahl und Eisen*, vol. xvii. pp. 723-728.

† *Wiedemann's Annalen*, 1897, p. 463; *Stahl und Eisen*, vol. xvii. p. 474.

‡ *Dingler's Polytechnisches Journal*, April 30, through the *Iron Trade Review*, vol. xxx. No. 38, pp. 12-13.

ratus which gave an autographic photographic record. Temperature was measured by a Le Chatelier apparatus, which photographed its record on the same plate. The rods were heated to bright redness and allowed to cool slowly. Copper rods similarly treated give regular curves, but with steel rods there are two breaks, one on heating and the other on cooling. The contraction at the critical point of heating, when heat is rendered latent, is much less than expansion at the point of recalescence on cooling. The contraction while heating takes place at the same temperature for all rods, but lasts longer when the carbon contents are lower. Similarly the expansion at recalescence lasts longer with lower carbon, but occurs at higher temperatures. The expansions and contractions seem to occur in two stages with softer steels or low carbon irons, but merge into one in hard steel. With higher temperatures of heating the effects are more marked, but long-continued heating or repetition of heating reduces the effect, or even removes it altogether, and burnt irons lack these qualities entirely. With hardened steels there is much irregularity, but the results appear to substantiate the theory that in order to harden a steel it must be heated at least up to the critical point of heating and quickly cooled at a temperature above the critical point of cooling. Tables of the coefficients of expansion for different temperatures and different carbon contents are given and discussed. In the author's opinion, contraction during heating may result from the rearrangement of molecules in the steel concomitant with the destruction of the crystalline structure and an absorption of heat due to the change of cement to hardening carbon, and *vice versa* on cooling. Although the contraction and expansion at the critical points differ, yet they may be and are compensated for by more gradual changes outside these points.

Relation of Tensile Strength to Composition.—A. C. Cunningham * deals with the relation of tensile strength to composition in structural steel, and for finding it approximately, 1000 lbs. is added for each 0.01 per cent. of carbon, and for each 0.01 per cent. of phosphorus to a base of 40,000 lbs. Other elements in normal steels are neglected. W. R. Webster's tables suited the steels he used, but have not proved to be of general application. H. H. Campbell's investigations have proved to be of greater value, and his conclusions are given by the author. Tables are given showing the strength of steels of various composition as calculated by Webster, Campbell, and himself, together with the average actual strength.

* *Proceedings of the American Society of Civil Engineers*, vol. xxiii. pp. 231-236.

H. K. Landis* has collected the various formulæ promulgated by different authorities for the purpose of correlating the tensile strength, elastic limit, reduction of area, and chemical composition of steel. For the percentage reduction of area Baron von Jüptner has given—

$$60 - (46.6C + 20Si + 10Mn)$$

as the result of 393 tests of all grades of steel, excluding the effect of phosphorus.

For elastic limit the following have been proposed :—

- 1,450,000 ÷ tensile strength on 8 inches, Pennsylvania firebox steel.
 1,500,000 ÷ tensile strength on 8 inches, American Society of Civil Engineers.
 42 - 36C - 5.5Mn - 6Si on 4 inches, Deshayes.
 30 - 27C - 4.1Mn - 4.5Si on 8 inches, Deshayes.
 $\{1,800,000 \div (\text{tensile strength} - 10,000)\} - 10$ on 8 inches, Johnson.
 $3 \div (C^2 - 10)$ on 8 inches, Johnson.
 33 - 60(C² + 0.1) when carbon is below 0.5, Howe.
 12 - 11.9 \sqrt{C} - 0.5 when carbon is above 0.5, Howe.

For tensile strength in lbs. per square inch the following have been given, the first factor being the base strength of supposed pure iron and C, Mn, &c., indicating the percentages of those elements. The authorities are I. and II., Osmond; III. and IV., W. R. Webster; V., Deshayes; VI., Von Jüptner; VII., VIII., and IX., H. H. Campbell; X., A. C. Cunningham; XI., Salom; XII. and XIII., R. Thurston; XIV., Bauschinger; XV., Weyrauch. The author gives the sources from which these are taken.

I.	{ 36,980 + 85,338C	+ 32,713Mn	+ 15,645Si	+ 92,450P.
II.	{ 36,980 + 66,137C	+ 39,868Mn	+ 15,645Si	+ 92,450P.
III.	34,704 + 79,993C	+ { 27,166Mn - 14,792Mn ² }	+ f(C)P	+ 50,065S.
IV.	32,570 + 79,993C	+ { 27,166Mn ₂ - 14,792Mn ² }	+ f(C)P	+ 50,065S.
V.	42,670 + { 25,601C + 51,208C ² }	+ 25,601Mn	+ 14,223Si	+ 21,334P.
XVI.	35,557 + 94,725C	+ 20,339Mn	+ 40,535Si.	
VII.	38,000 + 80,000C	+ 2,500Mn	+ 80,000Si	+ 20,000P.
VIII.	38,600 + 121,000C			+ 89,000P + R.
IX.	37,430 + 95,000C	+ 8,500Mn		+ 105,000P + R.
X.	40,000 + 100,000C			+ 100,000P.
XI.	45,000 + 100,000C			
XII.	60,000 + 70,000C			
XIII.	50,000 + 60,000C			
XIV.	61,870 + 61,870C ²			
XV.	52,625 + 52,625C			

* *American Manufacturer*, vol. lxi. pp. 151-153.

The very great variation between these is noticeable, and it is to be hoped that further experiments may give something more definite. Of course nothing that is perfectly exact is to be expected, for there are so many other circumstances that intervene, such as the heat treatment, the amount of working, and so forth.

The Elastic Limit.—H. K. Landis* again discusses the question of the elasticity of steel, and points out that the elastic limit, not the ultimate strength, is used in designing structures. Although, however, exacting specifications are made as to quality, no method is prescribed for carrying out the tests, and the result is that the elastic limit, as reported, is a very variable quantity. Test-pieces very generally are not taken from finished work, so that their physical properties depending on their treatment differs widely, though the chemical composition may be constant. Then there are three kinds of elastic limit, and the method of testing may result in any one of them being given, in spite of the fact that they range over a wide difference.

P. Krenzpointner† discusses steel from the engineer's aspect, pointing out the value of the elastic limit, and dealing generally with testing.

Testing Machines.—An illustration of a 100-ton Buckton and Wicksteed testing machine, built for the Dowlais-Cardiff works, has been published.‡ Plates up to 3 square inches in section can be tested in this machine at the rate of sixty per hour, and an accuracy of one in 5000 is guaranteed.

Punching Tests.—The use of punching as a method of testing, and the effect on the metal of that operation, is fully discussed by Pregel.§ Reference to earlier proposals embodying punching as a method of testing are given, and Fremont's measuring apparatus is described. In this, the punch as it descends causes the paper to travel over the pencil, which is connected by a lever to the frame of the machine so as to magnify the give in the latter as the punch passes through the metal. The diagram shows the work done as the punch point enters during

* *American Manufacturer*, vol. lx. p. 873.

† Paper read before the Engineers' Club of Philadelphia, through the *American Manufacturer*, vol. lx. p. 368.

‡ *Engineer*, vol. lxxxiv. p. 376.

§ *Dingler's Polytechnisches Journal*, July 16, through the *Iron Trade Review*, vol. xxx. No. 39, pp. 11-12.

the punching and shearing, and during the punching out of the blank. The effect of time, size, and the factors which bear on the difference in results are then discussed, after which attention is turned to the deterioration caused by punching and to the methods of obviating these effects.

The Results of Mechanical Tests.—O. Knaudt * discusses the degree of accuracy that is attainable in the testing of iron and steel. He instances a case in which samples of the same materials were sent to the testing laboratory at the Technical School at Munich, the Charlottenburg Testing Institute, and the Zürich Polytechnic. The samples had been previously tested at the works from which they were delivered. The testing laboratories above referred to are typical, and the appliances in use the best obtainable. Yet the results were not identical, as the following tables show :—

Tensile Strength (Tons per Square Inch).

	I.	II.	III.	IV.
Original works	23·1	23·9	22·4	21·9
Charlottenburg	22·2	23·2	22·3	21·6
Zürich	23·2	23·9	22·9	22·4
Munich	22·8	23·4	22·8	22·0

Elongation per Cent.

	I.	II.	III.	IV.
Original works	27·4	31·2	31·0	31·0
Charlottenburg	30·0	30·5	30·4	29·5
Zürich	29·9	32·6	29·9	28·4
Munich	27·2	28·2	32·4	29·4

Samples I. were from the works of Messrs. Schulz Knaudt ; samples II. from Messrs. Krupp ; samples III. from Hörde ; and samples IV. from Messrs. Thyssen & Co. The metal from which the samples were taken consisted of an ingot iron firebox plate. It will be seen that, as regards tensile strength, there was in some cases a considerable difference, while in the elongation tests this difference was marked ; and the author observes that from the results of these tests it may be con-

* *Stahl und Eisen*, vol. xvii. pp. 619-622, with one table.

cluded that, in the very best existing testing machines, variations of a ton and a half per square inch in the tensile strength and 5 per cent. in the elongation are not to be avoided, even with the most careful manipulation. The preparation of the test-pieces is a matter of the greatest importance, as some of the results show, which the author quotes. It must not be done at all in the cold.

Weld and Ingot Iron.—H. Tafel* observes that weld iron still plays a very important part for many purposes. A round bar of ingot iron can be turned down with a much cleaner surface than one of weld iron, however, and this leads to weld iron not being so generally applicable as might otherwise be the case. The author deals generally with the question of the applicability of these two kinds of iron. This paper gave rise to much discussion, in which the various different varieties of ingot metal were discussed, and cases mentioned in which weld and ingot metal have failed or have been successfully employed.

Structural Steel.—A long series of tests has been made by J. E. Greiner† on bridge members. Dimensioned sketches of the girders and photographic illustrations of the girders after testing are given, and the numerical results of the tests are given at length.

A general specification for structural steel is quoted and discussed by Stowell and Cunningham.‡ The steel is to be made by the acid-Bessemer, or the acid or basic open-hearth, and is divided into seven grades, ranging from very soft to very hard, having tensile strengths ranging from 50,000 lbs. and under to 80,000 lbs. and over. The elastic limit is to be half the ultimate strength, and various bending tests, elongations, and reductions of area are prescribed for the different qualities. The thickness of the plates are allowed for, and chemical tests are mentioned. It is believed that these tests recognise the importance of quality in addition to the tensile strength.

For the Victoria Jubilee Bridge over the St. Lawrence at Montreal, the specifications state§ that open-hearth steel is to be used with not more than 0.08 per cent. of phosphorus for acid steel, or 0.04 for basic steel. The physical requirements are as follows:—

* *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xli. pp. 482-483.

† *Proceedings of the American Society of Civil Engineers*, vol. xxiii. pp. 237-263.

‡ *Digest of Physical Tests*, vol. ii. pp. 180-196.

§ *Engineer*, vol. lxxxiv. pp. 328-329.

	Cast Steel.	Soft Steel.	Medium Steel.	Rivet Steel.	Eye Bars of 8 Sq. In. Area.	Eye Bars of more than 8 Sq. In. Area.
Ultimate strength, lbs. per square inch:—						
Maximum	...	62,000	68,000	58,000	...	...
Minimum	67,000	54,000	60,000	50,000	58,000	56,000
Elastic limit, lbs. per square inch:—						
Maximum	...	31,000	34,000	...	...	...
Minimum	34,000	27,000	30,000	...	30,000	29,000
Elongation, per cent.	{ 20 in 2 inches.	{ 25 in 8 inches.	{ 22 in 8 inches.	25	15 in 20 feet.	10 in 10 feet.

The influence exerted by variations in the velocities of the moving weights passing over bridges, on the bending of the metal work, and on the strains which result is considered by Zimmermann.* He compares the question with that of skating over thin ice. Here with the increasing velocity of the skater the bending of the ice film diminishes at the commencement of the run, but increases towards the end. The ice film is much more affected by rapid motion than by a slow and steady movement, though it may be that the movement is so rapid that the other side of the ice may be reached before the ice has had time to break. So, too, with iron bridges. The author has dealt with the subject mathematically in a book he has published under the title *Die Schwingungen eines Trägers mit bewegter Last.*†

The Strength of Corrugated Sheets.—Professor A. C. Elliott and G. Wilson ‡ have investigated the strength of corrugated sheets on a mathematical basis. The usual pitches are 3 to 5 inches, and the depth of the corrugation is a quarter of the pitch, and the gauge varies from 28 to 16 B.W.G., but sheets lighter than 24 B.W.G. are seldom used in this country. Tables are given for these standard and other sizes, showing the area of metal, moments of inertia and resistance, the safe sections for uniform distributed loads. By an experiment these are found to agree with practice. The question of the use of corrugated plates for roofing is then discussed.

Steel for Marine Forgings.—R. W. Davenport§ deals with the use of steel for marine forgings and shafting, and gives photographic

* *Stahl und Eisen*, vol. xvii. p. 466.

† Berlin: W. Ernst & Son.

‡ *Proceedings of the South Wales Institute of Engineers*, vol. xx. pp. 223-251.

§ *Cassier's Magazine*, vol. xii. pp. 513-530.

illustrations of some of the plant employed and the work produced in the United States. Up to the present a mild steel with a tensile strength of 28 to 30 tons and elongation of 22 to 28 per cent. has been used, but it becomes a question whether steel of higher elastic limit could not be successfully employed. With much harder steel the difficulties inherent to forging become more pronounced, but a great advance has been made by making the forgings and shafting hollow and by tempering them. For the latter process the axial hole through the shaft is very necessary to reduce the sectional thickness of the metal subjected to this operation. The removal of the core has but slight effect on the torsional strength of the shaft. The addition of nicked is also advocated. In addition to illustrations of hollow ingots and finished hollow propeller and crank shafts, pictures are given of the operations of hollow forging, fluid compression plant, and oil tempering plant.

G. W. Manuel* deals with crank and other shafts used in the mercantile marine, and discusses the use of iron, forged steel scrap, cast steel forged and machined into shape, mild steel, forged shafts, and nickel steel. Before the latter can be used to advantage the Board of Trade and Lloyds' rules must be modified to permit of the reduction in weight corresponding to the extra strength. Some tests of the materials are given, and illustrations of fractured shafts.

The Influence of Molybdenum on Steel.—W. von Lipin† observes that it is usually assumed that the influence of molybdenum on steel is identical with that of tungsten. If, however, the atomic volume theory enunciated by Roberts-Austen is true, this appears curious, as the atomic volumes of the two elements differ greatly, that of tungsten being 9·6 and that of molybdenum 11·1. Towards the end of 1896 the author prepared at the Putiloff Steelworks at St. Petersburg a steel containing—

Carbon.	Molybdenum.	Silicon.	Manganese.	Phosphorus.
0·54 to 0·55	3·72	0·1	0·13	0·024
with traces of sulphur.				

For the purpose of comparison a tungsten steel of similar composition was also prepared. This contained—

Carbon.	Tungsten.	Silicon.	Manganese.
0·55 to 0·56	3·80	0·07	0·13

* Paper read before the International Congress of Naval Architects and Marine Engineers through *Engineering*, vol. lxiv. pp. 74-75; *Engineer*, vol. lxxxiv. pp. 69-70, with illustrations.

† *Stahl und Eisen*, vol. xvii. pp. 571-572.

The ingots weighed in each case 50·7 lbs., and were crucible metal. The fusion was quite normal, and lasted about four hours. On pouring, the metal was sufficiently hot, and no rising was noticed. Both ingots were first treated under a 30-cwt. hammer, and then brought into bars of 0·9 inch section. In this process it was found that molybdenum steel, like the tungsten metal, must be very carefully heated, and the temperature must not, in fact, exceed a cherry-red, as it is very easy to burn the metal. Under these conditions the molybdenum steel could be readily hammered down. The surface was very clean and the metal very hard, while it was quite free from the small cracks and fissures which are so often present in tungsten steel. In fracture it was even, of a dark fine grain, and similar to the fracture of chrome steel. Similar test-bars of this metal and of the tungsten steel were then subjected to a number of mechanical tests, the results of which are given. These showed that the annealed tungsten steel had an elastic limit of 17·1 tons per square inch, a tensile strength of 39·6 tons, and an elongation of 15 per cent., while in the case of the molybdenum steel the elastic limit was 15 tons per square inch, the ultimate tensile strength 36·6 tons, and the elongation 18 per cent. The molybdenum metal is therefore the softer of the two. When hardened in oil and then subsequently annealed, the elastic limit of the molybdenum steel was only slightly raised, and the tensile strength entirely unaffected; such a treatment, therefore, which is of value for carbon and chrome steels, is almost entirely useless for molybdenum steel. Ordinary oil-hardening acted more energetically on the tungsten steel than on molybdenum metal. An energetic hardening in water has an entirely different result, the molybdenum metal becoming harder than the tungsten steel, although its elastic limit remains lower. Just as when treated in the hot, so in this testing the tungsten steel showed a tendency to longitudinal cracks, which was not the case with the molybdenum metal. Test-pieces of half-inch section could be bent double without cracking in the case of both the tungsten and the molybdenum metal. After hardening in water the tungsten steel could be bent down to the angle of 100° before they broke, while the molybdenum bars broke at the angle of 160°.

Considering the result generally, the author observes that molybdenum steel resembles on the whole tungsten steel, although annealing makes it softer and hardening harder than the latter. It stands treatment in the hot, too, better than the tungsten steel, and shows

no cracks, while the latter has a tendency in this direction. This may, perhaps, be the reason for the attempts which have been made to replace tungsten steel, and especially chrome tungsten steel, by molybdenum steel.

Nickel Steel.—W. Beardmore * describes the applications of nickel steel as an improved material for boiler shell-plates, forgings, and other purposes. Nickel steel with 0.26 per cent. of carbon has an elastic limit equal to the ultimate strength of ordinary carbon steel, and has all the properties of high carbon metal without its treacherous brittleness. It can be bent and punched quite as successfully as ordinary carbon steel, and the author has found no difficulty in welding nickel steel. Some tests on corrosion in sea-water have shown a loss of 1.36 per cent. in weight, as compared with 1.72 for mild steel and 1.89 for wrought iron. For tires the metal is very suitable. The usual test of a tire is that it should stand compressing one-sixth of its diameter without cracking; but one of nickel steel stood compression from a diameter of $39\frac{1}{2}$ to 19 inches without sign of fracture. A crack in the metal does not develop as in carbon steel, and this renders it peculiarly applicable for shafts and axles. Its uses for forgings and for the cylinders of hydraulic presses are also mentioned. Numerous tensile tests of nickel steel in the form of plates, bars, &c., are given by the author to show the ultimate strength, elastic limit, elongation, and contraction of area. The increased thickness now called for in boiler shell-plates is very great, as much as two inches and more being demanded, but the same strength would be obtained by using nickel steel plates 25 per cent. thinner, besides other advantages of decreased weight and more rapid transfer of heat. In temper-bend tests, nickel steel, if heated to about 1600° C. before quenching, gives satisfactory results.

Fluidity of Nickel.—Jules Garnier † has published an interesting paper on the fluidity of molten nickel. He showed that nickel, brought to a temperature well above its melting-point, could penetrate into channels in charcoal, which it filled in the form of wire as fine as hair, very flexible and very malleable. This illustration of the great fluidity of molten nickel may serve to explain the increase in resistance imparted by it to iron by filling up, like a gas does, all the intermolecular spaces in the iron.

* *Transactions of the Institution of Naval Architects*, vol. xxxviii. pp. 274-296.

† *Comptes Rendus de l'Académie des Sciences*, vol. cxxiv. pp. 1447-1448.

1897.—ii.

Boiler Plates.—E. D. Meier * gives in tabulated form a comparison of the regulations for boiler construction as set forth by the Board of Trade, Lloyds, United States Statutes, Bureau Veritas, and German Lloyds. In addition to the structural requirements, the table shows the tensile strength, elongation and contraction, and quenching tests for rivets, shells, flange plates, and stays.

A committee of the American Boiler Manufacturers' Association has recently presented † a report on materials and tests. The requirements previously proposed have been generally met as regards a maximum of 0.04 per cent. of phosphorus and 0.03 of sulphur. The tensile requirements are an ultimate strength of 55,000 to 65,000 lbs., elongation of 20 to 25 per cent. in eight inches, according to thickness, and bending tests are also prescribed. These specifications are compared with those prescribed by other bodies. Contraction of area and elastic limit are not mentioned in the requirements.

The Associations connected with the *Centralverband der Dampfkessel-Ueberwachungsvereine* ‡ have reported on the use of ingot iron plate in boiler construction. No Association referred to the explosion of boilers made of such material. It was pointed out in these reports that ingot metal, chiefly from the United Kingdom, had been employed at Ham-burgh and Stettin for the last twenty years in the manufacture of ships' boilers. Locomotive boilers had been made of it occasionally during the past ten or twelve years. All the Associations report that so greatly has the use of ingot metal for such purposes increased, that at the present time weld iron is only used when specifically required. Of late only German metal has been used. All the different Associations agree that for boiler construction there should be employed only basic ingot metal, soft, tough, and not capable of being hardened—a material such as is readily produced in the open-hearths of the German works. The harder metal used in former years, and mostly produced by the aid of the converter, was unsatisfactory. All Associations agree as to the necessity of a very careful testing of the plates, and they express the wish that they should meet the requirements now known in Germany under the name of the Wurzburg standard tests. For rivets only weld iron is used. Boiler-plates of soft ingot iron are found to work up extremely well in the boiler works, and as larger plates can be

* Paper read at the Convention of American Boiler Manufacturers' Association, through *Industries and Iron*, vol. xxiii. pp. 259-262.

† *Iron Age*, vol. lx. No. 6, pp. 17-20.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. p. 607.

made of the ingot metal than of weld iron, fewer welds are necessary. Some of the Associations require that the rivet holes should be drilled, and the necessity for careful annealing and the avoiding of all working at a blue heat is generally referred to. All the Associations report that in after practice such ingot metal boilers give satisfactory results. With regard to the question whether ingot metal rusts more than weld iron when used for boilers, no definite answer is given, but five Associations think it does. A committee has been appointed to inquire into this, but their experiments will require some years to complete.

Mild Steel for Boilers.—The use of open-hearth metal in boiler construction is discussed by Halfmann.* The author observes that while in many districts of Germany ingot metal is as much used as weld iron in boiler construction, this is not so in the case of the excellent kind of weld iron made in the neighbourhood of Remscheid. The author then deals with the manufacture of both ingot and weld iron, drawing attention to the differences in the two kinds of metal resulting from this. In weld iron it is the best and purest iron which will show the most blowholes, as it is hardest to weld. Weld iron contains only about one-fourth the amount of manganese contained in ingot iron, but, on the other hand, it contains five times as much phosphorus, carbon and sulphur being present in about equal quantities. Dealing next with the use of open-hearth metal for boilers, the author draws attention to the desirability of using good material, and points out that plates of too slight a thickness were first employed. The information gained in the practical use of these soon, however, led to their being replaced by thicker plates. The question of working ingot metal at a blue heat is then touched upon, and generally, the author observes, in using ingot metal for boilers, more care has to be taken than when weld iron is employed, though these difficulties are readily got over.

Mild Steel for Fire-Boxes.—With reference to the discussion on this subject, attention is drawn † to a correspondence published ‡ in the United States giving the results of mechanical tests of metal from an engine which was made in Philadelphia in 1877, and has since run some 800,000 miles, mainly in passenger traffic. This was one of thirty similar machines. For the first four years they were fed with wood, and for the subsequent sixteen years with coal from Iowa and Pennsylvania. The water at the eighteen stations was very variable

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. pp. 1092-1093.

† *Stahl und Eisen*, vol. xvii. p. 483.

‡ *Railway Age*, April 16, 1897.

in character, and occasionally left much to be desired. Analyses of the metal showed :—

Carbon.	Manganese.	Phosphorus.	Sulphur.	Silicon.
0.19 to 0.28	0.06 to 0.08	0.02 to 0.10	0.016 to 0.020	0.04 to 0.06

The thickness of the plate varied between 0.32 and 0.37 inch. The mechanical tests gave the following results :—Tensile strength, 27.9 to 32.4 tons per square inch, and elongation 25 to 36.5 per cent.

Brettman * considers the use of mild steel for locomotive fire-boxes. Reference is made to the discussion on this subject which has already appeared. It is pointed out that the results shown by Von Borries to have been obtained in connection with fifteen passenger locomotives and eight others in use on the Hannover lines in the years 1892 and 1893, would point to the assumption that while with very good feed-water ingot metal fire-boxes may be recommended for goods engines, yet the experience gained in Hannover would appear to show that they should not be employed for passenger locomotives. It is not only on the Prussian railways that unsuccessful results have attended the use of ingot metal for locomotive fire-boxes. Similar results were obtained in connection with the French railways. The reason why ingot metal has been so successfully employed for this purpose in the United States and so unsuccessfully in Europe is then considered. It is pointed out in the first place that the material employed is really different in the two cases, the American metal being exclusively acid open-hearth metal made of a pure pig iron. As Sauvage has shown, in the case of the Pennsylvania Railway Company, the stipulations as to the chemical composition of the ingot metal are, that it shall contain 0.18 per cent. of carbon, at the most 0.03 per cent. of phosphorus, not more than 0.4 of manganese, 0.02 of silicon, 0.02 of sulphur, and 0.02 of copper. As a rule, however, only mechanical tests are stipulated for. In Europe it is mostly basic open-hearth metal that is made. If, however, the difference in the results obtained is not due to any inherent difference in the metal, it might be due to a different treatment to which that metal was subsequently subjected. In Europe the locomotives are much less frequently in constant fire than in the United States. The heating-up and cooling-down to which the fire-boxes are subjected is therefore much more frequent, and this is probably the chief cause of the bad results which have been observed. It is only the inner fire-box, however, to which this general unfavourable result

* *Stahl und Eisen*, vol. xvii. pp. 644-648.

refers. In Europe, as well as in the United States, ingot metal has proved quite satisfactory for other portions of the boiler.

Considering the above editorially, *Stahl und Eisen** points out that the difference in thickness between the boiler-plate used in the United States and in Europe is probably one of the chief causes in accounting for the differing results in practice, and draws attention to Kreuz-pointner's remarks on this matter. †

Physical Properties of Compressed Iron Tires.—F. Grover ‡ has investigated the physical properties of compressed iron tires. In a recent process devised by West, the tires, instead of being shrunk on, are forcibly compressed into place by radially placed hydraulic rams acting on the cold tire. In one experiment the compressive stress brought to bear was 26 tons per square inch, during which the tire was reduced $2\frac{1}{4}$ inches in diameter, but in ordinary working a less pressure suffices. Tests on uncompressed bars, and on pieces cut from the tires after compression showed:—

Elastic Limit, Tons per Square Inch.		Maximum Load, Tons per Square Inch.		Extension per Cent. on 2 Inches.		Reduction of Area per Cent.	
Before.	After.	Before.	After.	Before.	After.	Before.	After.
14.4	20.6	23.6	22.7	19.5	...	19.08	...
14.3	15.2	24.1	25.0	30.0	27.5	28.7	17.0
14.0	17.8	22.5	24.8	23.0	13.0	19.3	9.5
...	22.1	...	26.3	...	...	...	...

The following conclusions are drawn:—(1.) That high compressive strains applied to iron bars result in raising the limit of elasticity in tension, and that the tension-limit may be changed from 61 to 91 per cent. of the maximum tensile strength by increasing the intensity of the compressive stress applied. (2.) That the tension modulus of elasticity is slightly lowered by the application of a high compressive stress. (3.) That a ductile iron bar presenting a perfectly fibrous fracture will, after the application of excessive compressive stress, be entirely changed to give a fracture of 100 per cent. crystalline area almost similar in appearance to that of cast iron. (4.) That annealing a compressed bar restores it to a fibrous state. Greater rigidity and endurance is produced by this means of setting the tires. When a reduction of more than 1 inch in 30 inches diameter is made, the tire should be annealed before closing it on the wheel. Illustrations of the fractures are given.

* Vol. xvii. p. 648.

† *Journal of the Iron and Steel Institute*, 1897, No. I. p. 544.

‡ *Engineer*, vol. lxxxiv. pp. 217-218.

Rails.—H. G. Prout* traces the development of the steel rail in the United States. In 1864 the price of iron rails rose to its maximum, and it then seemed as if the limit of endurance of railway track had been reached. The introduction of steel rails soon showed that weights and speeds could be increased to cope with increasing demands. The variations that have occurred in the form of the section of rails are then discussed at some length, with the aid of a number of figures, showing the changes that have taken place from the old pear-headed section through those proposed and used by Holley, Welch, Chanute, Sayre, Dudley, Hawks, Hunt, and others, to the standards adopted by the Committee of the American Society of Civil Engineers. Especial attention is directed to the alteration in practice whereby, instead of putting all the metal possible into the head to allow for wear, it is now more evenly distributed throughout the section, and the heads are made shallower and broader. Even now, however, uniformity is very far from being attained, but the tendency is towards simplicity and uniformity. The influence of the section on the manufacture and the wearing power is discussed, and attention is also given to the chemical aspect of the question.

G. W. Chance† suggests that a modified Whitworth hydraulic compression method of treating the fluid ingot steel should be used to obviate the effects of unsound ingots in rail manufacture. Cambering might be dispensed with if the rails were held straight in a tempering oven or on a table, and the heat abstracted from the head more rapidly than from the flange and web. A uniform texture would thus be produced, and a head obtained of equal elasticity with the web and bases. The head might be tempered harder than the other parts, but the safety of this is doubtful.

Since R. W. Hunt‡ gave his specifications for steel rails of heavy sections manufactured west of the Alleghenies, a large amount of these rails have been rolled. In some cases the carbon has had to be decreased, as it was not possible to obtain iron sufficiently free from phosphorus. They have proved to be safe, but of course it is too early to draw deductions as to wear.

Further discussion on the subject of rails has appeared in other

* *Engineering Magazine*, vol. xiii. pp. 567-578, 704-717.

† *Engineering and Mining Journal*, vol. lxiv. p. 220.

‡ *Transactions of the American Institute of Mining Engineers*. Chicago Meeting, 1897 (advance proof).

sources.* The chemical and physical requirements of rails, and their treatment in manufacture and use, are dealt with.

An interesting exhibit in the Brussels International Exhibition consisted of a historical series of rails, chairs, and sleepers used in Belgium. Some of the earlier rails of T section were rolled with an increasing depth of flange between the chairs to imitate the fish-bellied type. The increase in length and weight of the rails was well shown. Examples of early types of metal sleepers were also included to show the failure due to cracks starting from the corners of bolt-holes punched in too light sections.†

The important paper by Professor L. Tetmajer on changes involved in the preparation of basic steel for rails, and on the method of testing steel rails, which was abstracted in the last volume of this Journal,‡ has recently appeared in an English translation.§

A case is described by Ast,|| in which a length of rails had to be removed owing to excessive wear. Other rails had stood much better. Comparative tests were therefore made to ascertain why some rails had stood well while the others had worn so badly. Both mechanical tests and chemical analysis, however, were rather in favour of the badly-worn rails. Etch tests were then made, and these at once gave the desired information. The good rails were found to be homogeneous in texture, whilst the bad ones were wanting in homogeneity, and there can be no doubt but that it was this that caused the rails to show such poor results in practice. The following are some of the analyses and tests made :—

	Rail Head.	
	Bad Rail.	Good Rail.
Carbon, per cent.	0·27	0·30
Manganese, per cent.	0·34	0·23
Silicon, per cent.	0·01	0·03
Phosphorus, per cent.	0·04	0·15
Limit of elasticity, tons per square inch	21·14	20·57
Tensile strength, tons per square inch	27·94	35·05
Reduction of area, per cent.	6·40	26·90
Elongation, per cent.	6·00	19·00

* *American Engineer, Car-BUILDER, and Railroad Journal*, September, through the *Iron Trade Review*, vol. xxx. No. 37, p. 11.

† Communicated by H. G. Graves.

‡ *Journal of the Iron and Steel Institute*, 1897, No. I. p. 548.

§ A copy is in the Library of the Iron and Steel Institute.

|| *Stahl und Eisen*, vol. xvii. pp. 779-783; six illustrations.

In the rail web the bad rails showed from 21 to 29 per cent. of elongation. Another bad rail-head showed better tensile test results.

W. Müller* describes an arrangement for enabling the deflections of rails, bridges, &c., under moving loads to be photographically recorded. Briefly, the apparatus consists of a camera, of which the plate-holder is fitted to slide across the back by clockwork, so that a series of successive images may be taken upon one and the same plate at uniform intervals of time. The rail or beam to be observed has attached to it a brilliantly polished bead, which is photographed as a point of light, and the successive images of this point show the deflections. A second lens causes the images of a similar stationary point to be photographed upon the same plate in a line just below, thus furnishing a base line for comparison. The images are so close together that they practically form a continuous line, the deflection images giving an irregular curve, showing the movements of the rail, while the spacing of the points upon the base line are clearly enough defined to enable the intervals of time to be noted. It is, of course, essential that such an apparatus should be mounted upon a very solid foundation, as the least vibration of the camera would be fatal to the accuracy of the record; and the objective used must have great light-gathering power, owing to the feebleness of the illumination. The apparatus as installed in the North Railway Station in Vienna is fixed upon a masonry pier, is fitted with a Zeiss anastigmatic objective, and has given excellent results in practice.

The fact that rails creep has long been observed, but this shifting of position appears to be a final resultant of so many different causes that its full investigation is voluminous. J. von Engerth† has collected data from a number of the Continental railways, and from these he studies the problem. Especially is he indebted to Couard of the Paris-Lyons Mediterranean Railway, and to the report of Ast upon Austrian railways. In most of the roads investigated the creep was in the direction of the travel of trains, and also down the grades, as might be expected. The greatest creep observed was that on the Kaiser Ferdinands Nordbahn, where the maximum was 260 millimetres in one year; but this was exceptional, as on the same road the total creep for seven years was 420 millimetres. The creep, however, takes place on

* *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereines*, vol. xlix. pp. 85-87.

† *Ibid.*, vol. xlix. pp. 48-52.

straight level sections of road, and, furthermore, is not alike for both rails, the left rail almost invariably showing the greater creep.

Careful measurements were made upon about 500 miles of the Austro-Hungarian State railways, of which more than 300 miles are double track, and data were obtained upon the following points: Nature of ballasting, relative level of rails, width of embankments, character of rail-fastenings, length of time in which no creep occurred, and other special points that presented themselves. Couard, in his investigations, found that in double-track roads the creep was in the direction of train motion, and explains this action as follows:—When the engine wheels approach the end of a rail, the weight of the engine causes the rail to spring down a little lower than the end of the next rail, which has as yet none of the weight upon it. This causes the wheel to strike a blow upon the end of the rail which is being approached, and the horizontal component of this blow acts to drive the rail along in the direction of the motion of the engine. The greater creep of the left rail he explains by the fact that on the Paris-Lyons Mediterranean road, on which the trains keep to the left, the outer-rail, being farther away from the centre of the road-bed, is not so well supported as the inner rail, and hence suffers great deflection. For single-track sections, the creep appears to be in the direction of the faster trains or the heavier loads, thus bearing out the same theory.

The investigations in Austria, however, did not altogether support this view. Spitz, who assisted in making the examinations, found that the greater creep of the left rail also appeared on the Hungarian roads, on which the trains keep to the right, the left rail being in the middle portion of the road-bed, showing that some other cause must be found to explain the inequality. Local conditions, such as difference in ramming the ballast, unequal depths, &c., were found to cause unequal creep, and in some instances the creep was less down steep grades than on portions more nearly level. Spitz thinks that the true cause of the unequal creep of the rails is the action of the forces in the engines; he contributes an elaborate discussion of the successive impulses tending to produce blows upon the rails. Taking each side separately, he plotted the successive phases, and then, combining them into one diagram, showed the resultant to be in accordance with the observed facts. It would be interesting to apply the same analysis to the observations made in this country, and thus obtain a confirmation or refutation of this result.

Trials of Armour-Plate and Projectiles.—In a recent editorial article in the *Engineer*,* the recent improvements in armour-plates are commented upon, reference being made to the use of nickel and to the various systems of hardening the face.

Some trials have been made to determine whether surface cracks are prejudicial, whether machining before carburising is preferable to treating the rough rolled surface direct, and whether a fold or "lap" in the face of the plate caused weakness. The tests were made on two plates cut from a single larger one. Both were 8 by 6 feet by 6 inches in thickness. One had been machined before carburising the face. The projectiles used were five of Holtzer steel, 6 inches in diameter, and 100 lbs. weight, with a striking velocity of 1960 foot seconds. In both cases the plates withstood this attack, and broke up the shot. Only the plate that showed the "lap" was perforated by the broken shot when struck directly on that line, so that it had not more than a local weakening effect. Surface cracks made during manufacture and the machining had no effect of importance. Illustrations of the plates after the tests and the detailed results have been published.†

A successful trial of a 4-inch nickel steel armour-plate was made recently ‡ on board the *Nettle* at Portsmouth. The plate was 4 feet square and 4 inches thick, and had no wood backing behind. It was attacked by a 5-inch gun with Palliser projectiles. The first shot was fired with a velocity of 1406 feet per second, but the plate showed no sign of having been hit. The 50-lb. projectile simply splashed on the face. The second shot was fired with a velocity of 1750 feet per second, the plate being indented about three-quarters of an inch, but the face was not in any way broken. The third shot also had a velocity of 1750 feet, but the indentation was only half an inch. There were no cracks of any kind in the plate, but the projectiles were in every case broken to fine pieces.

Messrs. Vickers, Sons & Co.'s new nickel steel armour-plate showed some remarkable results under Government trials at Shoeburyness. The plate tested was 10 feet by 7 feet in diameter, and $11\frac{1}{8}$ inches thick, backed by 12 inches of oak. The requirements which the plate was called upon to satisfy were, that the plate should stand three shots from a 12-inch gun, two with a striking velocity of 1850 foot seconds, and the third with not less than 1800 foot seconds, without any part of the plate or projectile being driven completely through the wood

* *Engineer*, vol. lxxxiv. pp. 135-136.

† *Engineering*, vol. lxiv. pp. 287-289.

‡ *Industries and Iron*, vol. xxiii. p. 105.

backing, or the plate in any way cracking seriously. The first shot had a striking velocity of 1861 foot seconds, but the penetration was only $2\frac{5}{8}$ inches, with no cracks, whilst the projectile, a Holtzer of 714 lbs., was completely pulverised. The second shot gave a striking velocity of 1868 foot seconds, with practically the same result. The third shot had a striking velocity of 1860 foot seconds. The projectile collapsed, with a penetration of only $2\frac{1}{2}$ inches, the plate remaining, after the trials, practically uninjured.*

A table has been published† showing the effect of armour-piercing projectiles on Harveyed armour-plates. The effect of capping the projectiles is discussed, and also the penetrative power.

Some tests have recently been made of Hadfield's‡ armour-piercing projectiles. Two 6-inch shot with caps on their points were fired with velocities of 1960 and 1940 feet per second at a 6-inch Harveyed steel plate 8 feet square. Both passed through the plate, and were found broken up beyond. A 9-inch steel plate was also perforated and the shot unbroken.

L. E. Bertin§ deals with hardened armour-plates and broken projectiles. Tables are given showing particulars of a large number of trials in which the plates were or were not perforated, and the projectiles broken or not. The bearing of these on the thickness of the plate and its treatment, and on the form of the projectile and its manufacture are discussed.

The Micrographic Analysis of Metals.—A. Ledebur|| observes that some twenty years have elapsed since the original attempts of Martens to ascertain by the aid of the microscope the true inner structure of a mass of iron. Since then many other experimenters have also dealt with this subject, and much of importance has resulted. Still the majority of ironmasters are indifferent to the value of this mode of investigation or doubt its usefulness. There are many reasons for this. Care in the preparation of the specimens and experience in examining them are necessary, and frequently the results they attain do not reach the value they had anticipated. There is this difficulty, too, that the various experimenters who have dealt with the question are by no means in accord as to what has been observed,

* *Industries and Iron*, vol. xxiii. p. 177.

† *Engineer*, vol. lxxxiv. pp. 359-360.

‡ *Ibid.*, p. 260.

§ Paper read at the International Congress of Naval Architects and Marine Engineers, through *Engineering*, vol. lxiv. pp. 150-152, 211-214.

|| *Stahl und Eisen*, vol. xvii. pp. 302-309; ten illustrations.

and have given different names to the same things. The author refers to the work of Osmond on this subject, and to that of Sauveur and of Stead. Some microscopists believe that four, and others that five, different constituents are to be sought for. These include—

(1.) Ferrite, an iron considered to be free from carbon, but containing, possibly in a dissolved form, silicon, phosphorus, and other substances. According to Sauveur, this substance occurs in iron poor in carbon as polyhedral-granular aggregations containing included crystals of the cubic system; in semi-hard steel, as veins crossing the main mass of the metal; in steel with over 0.8 per cent. of carbon it disappears altogether.

(2.) Carbide, Fe_3C . When much carbon is present in the iron, it exists in this as a clearly separated constituent, and in veins not connected with each other, much harder than the main mass of the metal, being markedly different in this respect from the soft ferrite. Howe has given this material the name "cementite," and Osmond and Sauveur have adopted this name. According to the latter, ferrite and this cementite never occur together, but if both are produced simultaneously, then they combine to form the third constituent.

(3.) Perlite, according to Howe's classification, or sorbite, according to the nomenclature adopted by Osmond. At least a 300-magnifying power is required, according to Sauveur, to detect this constituent. It then appears either as scales or in a granular form. The scaly form exists in annealed metal or in metal which has at least cooled down slowly, and the granular form in steel which has been subjected to mechanical treatment during the cooling stage. With regard to the chemical constitution of this substance, nothing is as yet definitely known. Some consider it to be in the main a mixture of ferrite and cementite, but others doubt this, without stating any definite opinion as to what it really is. Perlite is present in every unhardened steel, and its percentage increases with the percentage of carbon present. If the steel contains 0.8 per cent., then the whole mass of the metal is stated to consist of this material. If the percentage of carbon exceeds this limit, the percentage of perlite is stated to diminish more and more, this constituent being replaced by cementite, Fe_3C . According to this view, 0.8 carbon steel should consist of 12 per cent. of cementite and 88 per cent. of ferrite.

(4.) The fourth constituent is iron containing carbon in a dissolved form, similar to that in which it exists in the molten metal. It has

no definite chemical composition. It is present in larger and larger quantities according to the degree of rapidity with which the cooling was effected. Osmond calls it martensite, and Howe hardenite.

(5.) This is a constituent observed by Osmond in semi-hard steels when they are hardened from a temperature of 690°C ., after having been first heated to 825°C . It is described as a transition form between ferrite and martensite, and has been named by Osmond troostite. Nothing is known as to its chemical composition; other observers appear so far not to have noticed this fifth constituent.

There exists, therefore, a difference of views between those which are based on chemical composition and those which are dependent on microscopic inspection, coupled with the admission that only guesses can be made as to the chemical nature of the substances observed. The author considers these different points of view, but he leaves it to the future to decide between them. The author quotes at length from J. E. Stead's paper on this subject,* and from that of A. E. Seaton read before the Institution of Naval Architects.

* *Journal of the Iron and Steel Institute*, 1897, No. I. p. 522.

CHEMICAL PROPERTIES.

Steel and Iron Alloys.—At the Engineering Congress of the Institution of Civil Engineers, R. A. Hadfield * discussed the subject of steel and iron alloys.

A. Carnot and Goutal † continue the study of the chemical condition of the elements which enter into the composition of castings and steels.

Manganese.—The experiments already described show that manganese has an especial affinity for sulphur and silicon, and that when it is in small proportion in a casting, it may be found entirely in the state of manganese sulphide or silicide. When it is in a large proportion, the solvents employed for iron cause the manganese to disappear at the same time.

Copper.—Potassium cupro-chloride does not allow of the isolation of the copper contained in a steel, but this may be effected easily by the use of a weak acid, such as hydrochloric acid at 5 per cent., if it is employed with the exclusion of air, *e.g.* in a current of carbonic acid gas.

Nickel.—Nickel disappears entirely under the action of the neutral potassium cupro-reagent.

Chromium.—Ferro-chromes of a high standard are not readily attacked by acids. Hence steels containing not more than 2.50 per cent. of chromium have been used. The insoluble residues consist of chromium, iron, and carbon.

Titanium.—The ferro-titanates may be attacked either by acids or by the cupric salt. The titanium is uncombined.

Tungsten.—The attack of a tungsten steel by dilute hydrochloric acid, at a gentle heat and with the exclusion of air, leaves as residue a compound of iron and tungsten of the composition Fe_3W .

Molybdenum.—Molybdenum steels, treated with dilute acids in the absence of air, leave a residue answering exactly to the formula Fe_3Mo_2 .

* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxx. p. 202.

† *Comptes Rendus de l'Académie des Sciences*, vol. cxxv. p. 221.

In fine, manganese, nickel, copper, and titanium seem to be simply dissolved in the steels; a portion of manganese may be in the state of sulphide or silicide in the cast metals.

Chromium forms complex and perhaps multiple compounds with iron and carbon. Tungsten and molybdenum are in the state of definite combinations with iron represented by the formulæ Fe_3W and Fe_3Mo_2 .

These elements, generally considered as metals, behave, therefore, in steel like non-metals, while arsenic, on the contrary, plays a part analogous to that of the true metals.

Preparation of Pure Iron.—W. M. Hicks and L. T. O'Shea* obtain pure iron by electrolysing a 5 per cent. solution of ferrous chloride, to which ammonium chloride has been added in quantity sufficient to form the double compound $\text{FeCl}_2 \cdot 2\text{NH}_4\text{Cl}$. Any ferric chloride which on electrolysis would form ferric hydroxide is removed by shaking with pure iron in powder. During electrolysis the content of iron must not be allowed to become less than 20 to 30 per cent. of the original quantity, and the cathode should be kept nearly immersed in the solution. The thin copper plate which serves as cathode is cleaned by washing with dilute nitric acid, rubbing with cotton-wool and fine sand, washing with potassium cyanide solution and finally with water. Swedish iron plate, containing 0.027 per cent. of sulphur and 0.049 per cent. of carbon, is used for the anode, and is placed in a porous cell in order to prevent the spongy carbon separated at the anode from reaching the cathode. The sulphur goes into solution as sulphate, and must be removed from time to time with the anode liquor. With a current of 0.08 to 0.2 ampère per 100 square centimetres of cathode surface at about 0.7 volt, the iron is obtained as a compact silver-white precipitate of velvety appearance.

Direct Production of Iron Carbide.—H. Moissan, † in melting iron with carbon in an electric furnace, finds that with increasing temperature the metal becomes more and more thick-fluid, until at about the melting-point of titanium it can no longer be poured. If the temperature is again lowered, the original fluidity is recovered, and solidification finally takes place at about the temperature of 1150°C . A grey mass results, which, like pig iron, contains much graphite, but in

* *Journal of the Chemical Society*, vol. lxxii. p. 374.

† *Zeitschrift für Elektrotechnik*, 1897, p. 127.

which, however, there is almost no combined carbon. If cast at 1300° or 1400°, white iron results, but if the mass of metal saturated with carbon is cooled suddenly by cold water from the temperature of 3000°, a product is obtained which is found to consist mainly of well-crystallised iron carbide of the formula Fe_3C . It may contain up to 5.25 per cent. of combined carbon. This carbide, Fe_3C , always forms when iron and carbon are brought together at high temperatures. The author describes a method for preparing it in a pure form. It then has the specific gravity 7.07, takes fire in air, when in a finely divided state, at a temperature below 150° C., and is rapidly decomposed by air containing moisture and carbon dioxide. It is not acted on by pure water.

Diamonds in Steel.—E. Demenge* gives a short history of the artificial manufacture of the diamond. Moissan has shown that carbon at high temperatures is transformed into graphite, and if great pressure is superadded, the carbon is altered to diamond. By very rapidly cooling molten iron in a bath of mercury covered with water, small octahedral fragments were produced. Some were black and others transparent; their density was 3.5 and they burnt in oxygen at 1000° C. Both A. Rossel and L. Franck† also have obtained small diamonds from hard steels produced at a high temperature and cooled under great pressure, and from various forms of iron and steel. Franck found one of considerable size as compared with those that generally occur in a blast-furnace bear.

Ferrosilicon.—E. Donath and M. Hailsig‡ observe that under certain conditions the percentage of silicon that passes into pig iron can be considerably increased. As soon as the percentage exceeds 5, the product is described as a ferrosilicon. As a rule, ferrosilicons do not contain more than 15 to 16 per cent. of silicon, though Gauthier has pointed out that some are made with 20 to 30 per cent. or more.

With regard to the analysis of ferrosilicon, little has as yet been published, and even very little with reference to the chemical nature of the material. Notwithstanding the fact that silicon induces the separation of carbon in the form of graphite, analyses of high silicon ferrosilicons always show a percentage of combined or amorphous car-

* *Génie Civil*, vol. xxxi. pp. 41-42.

† *Journal of the Iron and Steel Institute*, 1896, No. II. p. 421.

‡ *Stahl und Eisen*, vol. xvii. pp. 670-673.

bon. The authors have had frequently to examine such ferrosilicons, and this has led them to make a more detailed examination of the question. They have in the first instance submitted to careful examination an alloy containing 14.32 per cent. of silicon. It is probable, they observe, that all other such alloys would show similar results. Dilute and concentrated hydrochloric acid, nitric acid, and even nitrohydrochloric acid has scarcely any action, or but a very slow one, even when the alloy is finely divided. They cannot be brought into solution in this way. To do this it is necessary to powder them extremely fine, and then to fuse them with sodium carbonate and nitre. In the fused material all the constituents of the alloy can then be determined with the exception of the carbon. The authors determined to decompose the alloy by the use of sodium copper chloride, and so to determine the total carbon; but in this they were only partially successful. In the cold it is almost without action; on heating a reaction ensues, but this completely stops before the ferrosilicon has been completely decomposed. The authors have found that ferrosilicon can be very readily dissolved by aqueous hydrofluoric acid. It acts most energetically, yielding gaseous hydrocarbons. The solution has therefore to be effected in a very large-sized platinum dish, well covered, a hole being left in the middle of the lid. The hydrofluoric acid must be added very slowly. Towards the end of the reaction, heat should be applied gently. As soon as the first violent reaction is at an end, more hydrofluoric acid should be added, and the treatment continued until no further gas bubbles can be detected. The whole mass in the dish is then treated with fairly concentrated sulphuric acid to decompose the fluorides, the sulphuric acid evaporated off, and then the mass re-treated with hydrofluoric acid and sulphuric acid as before. The material is then dissolved in moderately concentrated hydrochloric acid, using heat, diluted, filtered through an asbestos tube, such as is used for invert sugar determination, washed with hot water, and dried at 120° to 130° C. Graphite was clearly marked in the residue so obtained. The quantity of residue amounted in two cases to respectively 1.50 and 1.52 per cent. It was found to contain:—

	I.	II.
	Per Cent.	Per Cent.
Carbon	94.898	94.829
Hydrogen	0.345	0.379
Ash	4.698	4.723

The ash contained 1.425 per cent. of silica and 3.28 per cent. of ferric oxide. These results represent a percentage of carbon in the original material amounting to 1.42 and 1.44 per cent., and the whole of this must be considered as graphite. As, however, some of the carbon escaped as hydrocarbons during the solution, carbon must be present in the alloy in another form in addition to the graphite. The authors made a number of experiments in the wet way to determine this carbon, but unsuccessfully. They then made an ordinary combustion, using lead chromate. In two experiments made the percentage of total carbon found was 2.78 and 2.81. Subtracting the graphitic carbon, this left in the two cases 1.36 and 1.39 per cent. respectively for that form of carbon which escaped as gas. It could not well be "combined" or amorphous carbon, because a hot chromo-sulphuric acid solution had been without action, and the authors believe that silicon carbide is present in the ferrosilicon. To prove this, they have compared the action of ferrosilicon with carborundum, as regards the action of chromo-sulphuric acid, and the results bore out this impression. By treating the ferrosilicon in a current of dry chlorine and subsequent treatment with chromo-sulphuric acid, carbon percentages of 2.793 and 2.73 were observed. These thus agreed with the results obtained by the aid of combustion with lead chromate. In conclusion, the authors point out that a portion of the carbon occurs in ferrosilicon in the form of graphite, and a portion in some other form as yet uncertain. If silicon carbide is present, then it must exist in a very finely divided form, and it is possible that the non-graphitic carbon may be contained in a ferrosilicon carbide of some kind.

A Carbide of Silicon.—L. Franck * describes a carbide of silicon high in carbon and resembling the diamond. The use of calcium carbide as a deoxidising agent in iron manufacture has been frequently suggested. The author has examined metal that had been treated in this way to ascertain what change had taken place in the carbon of the carbide and whether, perhaps, graphite-like forms had not been formed. It was found that a silicon carbide occurred in somewhat large quantity, showing well under the microscope. The iron was dissolved by the method already described and adopted by Moissan, the silicon compounds decomposed by hydrofluoric acid, the graphite separated by Moissan's method, and the residue purified with nitro-hydrochloric,

* *Stahl und Eisen*, vol. xvii. p. 48.

hydrofluoric and concentrated sulphuric acids. The residue, though small in quantity, showed well-developed crystals. These were partly bluish-white in colour, and partly yellowish or of a greenish tinge. They resembled diamond powder. They were mostly octahedral in form. The parallel marking strikingly resembles that of the diamond. The specific gravity varies from 3.10 to 3.30, and the particles scratch ruby. On enlarging one thousand times, it was found possible to detect that polarised light was not without action on the whole of the particles under examination. A similar experiment with pure diamond powder showed polarised light to be without action. The author succeeded in obtaining about 400 milligrammes of this diamond-like powder, and one-half of this was used for the determination of the carbon by heating it in a platinum boat with lead chromate to a temperature of a little over 1000° in a Berlin porcelain tube, through which a constant current of oxygen was passed. The other half was used for the determination of the silicon. This portion was heated gradually to complete fusion with sodium potassium carbonate in a platinum crucible, and continued in this state for a total period of six hours. The carbide was in this way converted into silicate, from which the silica was separated in the ordinary way. The analysis showed the material to contain:—

Silicon.	Carbon.
14.34	84.95

Further experiments showed that this carbide was not formed in the iron, but that it existed in the calcium carbide used, and it seems probable that the higher the percentage of silicon contained in the material from which the calcium carbide was made, the higher will be the percentage of this silicon carbide in the calcium carbide used.

Action of Boron on Iron.—According to H. N. Warren,* boron-eisen can be obtained by melting ferric borate under a layer of borax, and the compound obtained scratches flint. Moreover, iron becomes contaminated with boron merely by heating the cast metal with fusible borates, or by reducing its oxide by means of carbon in the presence of a fusible borate, the amount of boron thus entering into combination amounting to from $\frac{1}{2}$ to 2 per cent.

Peculiar Forms of Iron.—T. H. Norton† describes two peculiar forms of iron. The first was taken from a deep crevice in a blast-

* *Chemical News*, vol. lxxv. p. 91.

† *American Chemical Society*, vol. xix. p. 2.

furnace hearth, where it must have been molten for over a year, and then have cooled very slowly. It is light, silvery and crystalline, with a rectangular cleavage. At the same time it is very malleable, and is scarcely touched by the drill. After hardening, a few strokes of the hammer made it malleable again, and the original mass could be split up into cubes, which flattened out to thin plates under a hammer. Analysis showed :—

Mn.	Si.	S.	P.	C.
0.0362	0.0262	0.0106	0.8285	0.1035

The second sample was a piece of wire which had supported an incandescent mantle, and where it was exposed to the flame it had become very brittle. Analysis showed 0.0362 per cent. of carbon in the unaltered portion and 0.0978 in the altered part.

The Condition of Phosphorus in Steel.—E. D. Campbell and S. C. Babcock * describe some experiments on the influence of heat treatment and carbon upon the solubility of phosphorus in steel. Samples of the metal were raised to between 900° C. and 1000° C., and allowed to cool slowly, or were quenched in water at 4° or 5° C. from various temperatures. The amount of phosphorus soluble in an acid mercuric chloride solution was then determined by methods which are fully described. The results are given as follows :—

Chemical Composition.			Heat Treatment.	Quenching Temperature.	Per Cent. of Phosphorus Soluble in Acid HgCl ₂ .	Per Cent. of Total Phosphorus Soluble in Acid HgCl ₂ .
C.	P.	Mn.		°C.		
0.10	0.119	0.484	Annealed	...	0.099	83.2
0.10	0.119	0.484	...	719	0.081	68.08
0.10	0.119	0.484	...	825	0.079	66.4
0.10	0.119	0.484	...	928	0.080	67.2
0.10	0.119	0.484	...	1,028	0.086	72.2
0.37	0.160	0.820	Annealed	...	0.137	85.6
0.37	0.160	0.820	...	728	0.110	68.8
0.37	0.160	0.820	...	827	0.066	41.2
0.37	0.160	0.820	...	923	0.048	30.0
0.37	0.160	0.820	...	1,027	0.049	30.6
1.22	0.098	0.780	Annealed	...	0.098	100.0
1.22	0.098	0.780	...	719	0.087	89.8
1.22	0.098	0.780	...	750	0.051	52.0
1.22	0.098	0.780	...	825	0.018	18.3
1.22	0.098	0.789	...	923	0.015	15.3
1.22	0.098	0.780	...	1,023	0.016	16.2

* *Journal of the American Chemical Society*, vol. xix. pp. 786-790.

This shows that phosphorus, like carbon, is capable of existing in steel in at least two forms, and that the influence of phosphorus upon the physical properties of steel in which it is contained is as much dependent upon the form of combination in which it exists as upon the quantity. This power of phosphorus to exist in two or more forms in steel, with the varying influence on the brittleness of the steel according to the form present, may account for many of the apparent inconsistencies in the statements usually made by metallurgists in regard to the behaviour of this element.

The Corrosion of Iron and Steel.—To protect iron from rust, at Ebensee* it has been coated with a mixture consisting of 60 per cent. of soda water-glass, 20 per cent. of powdered asbestos, and 20 per cent. of barium sulphate. This mixture is found to thoroughly protect iron from rust, provided the iron has a clean surface free from rust before it is applied. Sheets coated with this material have been used for some time at a temperature of 120°, and show no signs of oxidation. This coating resists the action of acids.

In view of the increasing use of iron in building construction, the action of mortar upon iron should not be overlooked. If a piece of wrought iron is placed in freshly prepared lime mortar, it rapidly oxidises, and this oxidation is not confined simply to the surface of the metal. Gypsum also induces oxidation, although not quite to the same extent; cement, on the other hand, appears to be an excellent preservative of iron from rust. Pieces of iron coated with a thin layer of cement did not rust even when left for a long time in water.†

Observations have been made on corrugated iron roofs in railway stations which show that, to minimise rusting and other action of the products of combustion, there should be made free provision for their exit. The gases from coke have a more marked effect than those from coal.

It is often supposed that the corrosion of iron underneath the paint is due to the penetration of air and water through minute cracks in the protective covering. Some recent experiments‡ made in Germany show, however, that these fissures do not exist, but that the paint films are themselves hygroscopic and swell in the presence of moisture, so becoming porous and allowing diffusion. This increases with the

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 498.

† *La Revue Technique*, 1897, p. 284. *Baumaterialienkunde*, July 1.

‡ *Engineer*, vol. lxxxiv. p. 389.

amount of pigment in the paint. Slow-drying paints put on in several layers are to be preferred.

Iron articles which have become greatly attacked by rust can be very readily cleaned by plunging them into a fairly concentrated solution of stannic chloride. They should be left in for, as a rule, about twelve to twenty-four hours. The solution should not contain an excess of acid.*

Action of Iron on Solutions of Metallic Nitrates.—Jean B. Senderens† has studied the action of different kinds of iron (wrought iron, piano wire, &c.) on dilute solutions of silver salts, and finds that unworked iron is far more active than worked iron, precipitating the silver readily from dilute solutions of the nitrate. This he attributes to a difference in the physical condition in the different samples of iron.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 580.

† *Bulletin de la Société Chimique*, vol. xv. pp. 691-700. See p. 76 of this volume.

CHEMICAL ANALYSIS.

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I.—ANALYSIS OF IRON AND STEEL.

Works Laboratories.—The amount of work that has to be done daily in the laboratory of an ironworks is referred to by Kintzlé.* He mentions a case in which, at the laboratory of a basic steelworks which had an out-turn of 133,000 tons (8351 charges) during the period July 1, 1896, to January 1, 1897, 59,076 samples were analysed during this period. In this laboratory were employed three chemists and six assistants, and seven workmen were also employed in taking and preparing the samples. The number of analyses made daily averaged over 400, and included 170 manganese determinations, 70 sulphur, 90 phosphorus, and some 70 of other kinds, such as carbon, phosphoric acid, ash, &c. The time required for the various determinations in this laboratory is as follows :—Manganese in pig iron, 4½ hours, and in steel, 3 hours ; sulphur in pig iron, 12 hours, and in steel, 10 hours ; phosphorus in pig iron, 5 hours, and in steel, 4 hours ; carbon in pig iron, 6 hours, and in steel 45 minutes ; silicon, 20 hours ; phosphoric acid, 3 hours, and ash, 5 hours. Full use is made of volumetric methods. For rapid works determinations, manganese is determined roughly in steel in 20 minutes, sulphur in 2 hours, phosphorus in 30 minutes, carbon in 30 minutes, silica in 30 minutes, and phosphoric acid in one hour. While it is of course impossible that absolute accuracy can be obtained when such an enormous number of

* *Stahl und Eisen*, vol. xvii. pp. 382-383.

determinations have to be made daily, yet the errors are relatively very slight, as shown diagrammatically in the cases of manganese and phosphorus, the results of a large number of check assays being shown. The number of tensile tests made during the period in question was 10,708—from 70 to 75 a day, that is. The author refers generally to the importance of the question.

Determination of Carbon.—E. Donath* and W. Ehrenhofer discuss the determination of carbon in iron and steel by the gas volumetric method. The authors have used this method for steels of very varied character for the past six years. Experience with other methods as well as this one has shown them its disadvantages as well as its advantages. The Wiborgh apparatus is made much too small, with the result that even in mild steels only a very small quantity of material can be taken for analysis. The apparatus, too, possesses the disadvantage that the absorption of the carbon dioxide is effected with caustic potash solution in the measuring tube itself, with the result that it is necessary to take the apparatus to pieces before every experiment, and to wash the measuring tube with water and acid. The authors modified the method by first collecting and measuring the carbon dioxide, and then subsequently absorbing it with caustic potash solution. Thörner has modified the apparatus in a similar manner, but the authors consider the modified apparatus as devised by him too complicated when it is a question of making many carbon determinations in the day. Lunge and Marchlewski have perfected this method of determination. The authors, however, considered that some simpler form of the apparatus was necessary for works laboratories, and they now describe such an apparatus as devised by them, and also describe its method of use. From 0.2 gramme to 4 grammes of the pig iron or steel, according to the percentage of carbon, is taken for the analysis, and treated in a flask with about 5 cubic centimetres of copper sulphate solution for each half-gramme of iron taken for analysis, stirring, and adding a small crystal of copper sulphate, free from acid, from time to time. When the carbon has been separated a measuring flask is got ready in a way the authors describe, and connected with the dissolving flask. An absorption vessel is also filled up to the mark with caustic potash solution. Into the dissolving flask, still containing the copper vitriol solution, about 0.2 gramme of

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 284-286; three illustrations.

solid chromic acid is charged for every 0.001 gramme of carbon considered likely to be there. The dissolving flask is stoppered, and a mixture of 100 parts of concentrated sulphuric acid and twenty parts of water is charged in through a funnel in quantity sufficient to nearly fill the dissolving flask up to the neck. The subsequent treatment is similar to that of the ordinary Wiborgh method. When the gas has been measured, it is subjected to absorption by caustic potash in a way similar to that used in the Orsat method of gas analysis. The authors illustrate their apparatus, and fully describe the details of its use. They enumerate its advantages, the chief of which is its simplicity and adaptability to use at works laboratories. For steels containing less than 0.3 per cent. of carbon, four grammes of the metal is taken for the analysis, and for higher percentage metal smaller quantities, as already mentioned.

Determination of Carbon in Ferro-Chrome.—According to H. Brearley and R. L. Leffler,* the pulverised ferro-chrome is mixed with pulverised lead chromate, placed in a boat, and burnt in a current of oxygen in a tube packed with copper oxide. The reaction in the boat, which has to be assisted by heating with a foot blowpipe, takes place with great rapidity at one stage and is sluggish at another; therefore a reservoir is interposed at the oxygen supply end to accommodate the rush of gas and to subsequently permit of its steady passage through the tube. Moreover, the tube is protected against the great heat by wrapping it first with paper and then with asbestos millboard, the paper leaving a layer of ash that prevents the asbestos fusing to the glass; millboard is also used to prevent the porcelain boat employed from fusing to the tube. Zinc oxide and litharge used instead of lead chromate did not give satisfaction; with copper oxide, the heat has to be greater and the reaction is less violent; but lead dioxide is effective and convenient, for it does not require the aid of a blowpipe flame.

Determination of Manganese.—According to F. Ulzer and J. Brüll,† the liquid, after being freed from iron by means of zinc oxide according to Volhard's directions, is mixed with 20 cubic centimetres of a 5 per cent. solution of hydrogen peroxide. Aqueous soda is added

* *Chemical News*, vol. lxxv. pp. 241-243; *Journal of the Chemical Society*, vol. lxxii. p. 386.

† *Chemisches Centralblatt*, i. 769; *Journal of the Chemical Society*, vol. lxxii. p. 350.

as long as a precipitate forms, and the mixture is boiled. When cold, a standard solution of oxalic acid is added, and then dilute nitric acid; the mixture is heated nearly to boiling, and the excess of oxalic acid in the clear solution is titrated with standard permanganate solution.

The best solvent for the iron is a mixture of 10 volumes of nitric with 2 volumes of sulphuric acid and 10 volumes of water; during the evaporation of the solution 10 cubic centimetres of hydrochloric acid is added. The liquid should contain about 0.1 gramme of manganese.

H. Brearley,* after searching investigation, adopts the following method. One to 1.5 gramme of 20 per cent. spiegeleisen, or a proportionate amount of other manganiferous iron, is dissolved in hydrochloric acid, oxidised with nitric acid, filtered, if necessary, through a small asbestos filter, neutralised with sodium carbonate, diluted to about 900 cubic centimetres and treated with a 3.75 per cent. solution of sodium acetate at the rate of 20 cubic centimetres per gramme of iron. It is then boiled and measured, noting the temperature; enveloped in cloth to retard cooling, and half the volume siphoned or filtered off, again noting the temperature; the liquid is cooled, neutralised with sodium carbonate, acidified slightly with acetic or sulphuric acid, then run into sufficient 0.3156 per cent. potassium permanganate solution containing 10 cubic centimetres of 20 per cent. zinc sulphate solution, shaking constantly, allowed to settle, an aliquot part filtered off, acidified and determined with ferrous ammonium sulphate, and permanganate. Corrections being made for the variations in volume due to temperature, the calculations are as usual.

G. Giorgis† modifies Volhard's process for determining manganese as follows. The solution of the blast-furnace or other product containing iron and manganese is treated with sodium carbonate until a slight precipitate forms, which is then dissolved by nitric acid free from nitrous acid, and the solution diluted to standard volume. A known volume of $n/20$ potassium permanganate, more than sufficient to oxidise all the manganese present, is boiled for some time in a basin with a large quantity of sodium nitrate and an aliquot part of the manganese and iron solution; after cooling and diluting to a standard volume, an aliquot part of the solution is separated through an asbestos filter, and the excess of permanganate titrated with $n/20$ chromium sulphate solution. From the excess of permanganate thus

* *Chemical News*, lxxv. 13-16; *Journal of the Chemical Society*, vol. lxxii. p. 233.

† *Gazzetta*, vol. xxvi. ii. 528-536; *Journal of the Chemical Society*, vol. lxxii. p. 350.

ascertained, the quantity of manganese in the original solution can be calculated.

This method is not directly available for the estimation of chromium; if chromium, but not manganese, be present, the former can be determined by substituting for the sodium nitrate added to the boiling permanganate solution, a solution containing 40 grammes of potassium carbonate and 0.5 grammes of potash per litre; this is added to the permanganate solution, which is then boiled with the chromium solution for a short time, after the latter has been neutralised with sodium carbonate. The excess of permanganate used is determined as before.

If the solution contains iron, manganese, and chromium together, it is treated with sodium carbonate, clarified with nitric acid, and boiled for some time with excess of permanganate containing much sodium nitrate; the liquid is then rendered alkaline by adding the above solution of potassium made up to a standard volume, an aliquot part filtered off through an asbestos filter, and the excess of permanganate used determined as before. The quantity of permanganate requisite to oxidise both chromium and manganese is thus ascertained, and by determining one of these metals by either of the methods described above the quantity of each present can be found.

The test analyses gave good results.

Determination of Phosphorus.—L. Schneider* has investigated in detail all the stages of the determination of phosphorus by the molybdate method, so many and varied suggested modifications of this process having from time to time been made. In different laboratories different modifications are adopted, and the results obtained are consequently not concordant. Dealing in the first place with the question of solution, the author observes that this is effected by means of nitric acid of different degrees of concentration. Several writers suggest for this an acid of 1.4 specific gravity. This corresponds to the specific gravity of the ordinary commercial concentrated acid. Acid of this kind, however, is at first without action on the iron filings, and when the aid of heat is resorted to, the action is for the time exceedingly violent, but this soon ceases, owing to the relative insolubility of the iron nitrate formed in such concentrated acid. Undissolved iron remains behind, and this is now less readily dissolved. The solution is much better effected in nitric acid of 1.2 specific gravity. The use

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 326-328, 344-347; *Stahl und Eisen*, vol. xvii. pp. 769-775.

of the concentrated acid is doubtless intended to prevent the formation of phosphoretted hydrogen or lower oxides of phosphorus. The author shows, however, experimentally that no phosphoretted hydrogen is formed, even when such dilute nitric acid as that of the specific gravity 1.1 is employed. The oxidation, however, is never complete even when concentrated nitric acid is employed. The solution, it is true, contains the whole of the phosphorus, yet not all in the form of phosphoric acid. Various writers have stated that too little phosphorus is always found unless before precipitation the nitrate solution is evaporated to dryness, and then heated until the ferric nitrate has been decomposed, and various suggestions have been made to account for this.

In earlier experiments in the case of a phosphoric iron containing 14.6 per cent. of phosphorus, the author showed that after dissolving in nitric acid, some of the phosphorus remained in the form of the trioxide, unless some more energetic oxidising agent was subsequently employed, and escaped precipitation when the molybdate was added. The author observes that as Ledebur still maintains that the whole of the phosphorus is oxidised to pentoxide, he has made further experiments, using copper phosphite, and these have shown that the phosphorus in this is never completely oxidised to the pentoxide, and that nitric acid of 1.2 specific gravity is just as strong an oxidising agent in this case as that of the specific gravity 1.4. He further found that even in the cold a further oxidation ensued, when solution of potassium permanganate was employed; but that this oxidation was not completely effected except at a boiling heat. The author tabulates eighteen oxidation agents, as shown by Bancroft, and of these a mixture of potassium permanganate and sulphuric acid is the most active. The manganese peroxide that ensues can be readily brought into solution, the author preferring the careful addition of oxalic acid until a complete solution has resulted, but ferrous sulphate or tartaric acid may also be used, provided too great an excess of the latter is not employed. Some oxidising agent in addition to the nitric acid is always necessary.

Dealing next with the precipitation, the author shows in tabular form the very different proposals that have been made for the molybdate solution, both as to the percentages of molybdic acid and of nitric acid, and the quantity of ammonium nitrate. He shows from experiments with solutions of different strengths that if it is desired to precipitate in the cold, the percentage of molybdic acid must not be less than 2, and the solution undergoing precipitation should be preferably allowed

to stand for twenty-four hours. By using a precipitating solution containing 4 per cent. of molybdic acid the solution can be effected much more rapidly. In the various molybdate solutions proposed, the nitric acid varies between 7 and 30 per cent. It was found that the higher percentages of nitric acid did not hinder the precipitation or interfere with the accuracy of the results. On the other hand, if the molybdate solution is nearly neutral, on the addition of sodium phosphate no precipitate results. The percentage of ammonium nitrate in the solution varies between 5 and 30. The author shows that in comparative experiments better results were obtained with precipitating solutions containing larger quantities of ammonium nitrate and free nitric acid than when a weaker solution was employed. The molybdate solution that it is intended to employ should be always carefully standardised in advance to ascertain its value as a complete precipitant for the phosphorus. For precipitation in the hot a molybdate solution must be employed, which even at that temperature does not of itself undergo precipitation.

The determination of the precipitate is next dealt with. This should be washed on the filter with a solution containing 8 per cent. of nitric acid and 10 per cent. of ammonium nitrate, and subsequently with a very little pure water. The precipitate should be dissolved off the filter with ammonia into a porcelain crucible, evaporated on the water-bath, acidulated with a few drops of nitric acid, again evaporated, and finally heated in the crucible on an asbestos plate over a gas-burner for a quarter of an hour. The ammonium nitrate is completely driven off, while the precipitate itself is not decomposed even with a prolonged heating on the asbestos plate. The precipitate has then the composition $12\text{MoO}_3 \cdot \text{PO}_4(\text{NH}_3)_3$, and contains 1.65 per cent. of phosphorus, if 96.0 is taken as the atomic weight of molybdenum.

Referring to the question of the titration of molybdic acid, the author observes that this question is still unsettled. The author himself finds that molybdic acid can be completely reduced to the sesquioxide by the use of zinc and sulphuric acid, but that this is very readily re-oxidised again by the oxygen of the air, consequently rendering the titration inaccurate. The author next refers to the question of error, due to the presence of dissolved silica and arsenic acid and other substances. The author found that the presence of titanous acid, tungstic acid, and silica, which of themselves give no precipitate with the molybdate solution, did not affect the accuracy of the results obtained, but arsenic passes into the precipitate even at ordinary tem-

peratures and when only small quantities of arsenic are present. In the presence of tungstic acid it must be remembered that this is not completely precipitated by acids until after twenty-four hours, so that the phosphorus precipitation should not be commenced until this has had time to be completed.

H. Wdowiszewski,* of the Kulebaki Ironworks, describes a method for the rapid determination of phosphorus. By thoroughly shaking the solution during the precipitation with magnesia mixture, the time required for the precipitate to settle is very greatly diminished. He gives the results of twenty-four comparative tests, in which, in one case, the solution during precipitation was shaken for five minutes, and in the other allowed to stand for twenty-four hours. In every case the quantity obtained by shaking was either in excess of that obtained by standing or was identical. The author considers that this is due to the fact that the longer the precipitate is allowed to stand in contact with the ammoniacal solution the larger is the quantity of it which is dissolved, and he gives proof of this from the results of test experiments. Shaking he considers the only accurate method. The method he adopts in determining the phosphorus in pig iron is as follows:—Two grammes of the pig iron is dissolved in 30 cubic centimetres of nitric acid of 1.2 specific gravity. When the whole of the metal has been dissolved, the solution is diluted to 50 cubic centimetres, and the silica and graphite filtered off. The filtered solution is then brought down to the original volume by evaporation, oxidised with permanganate, hydrochloric acid added to dissolve the peroxide of manganese, and then, after cooling, neutralised with ammonia. The solution is then heated to 60°, and molybdate solution added. The solution is first shaken for five minutes, and then allowed to stand in a warm place for a quarter of an hour. The precipitate is then filtered, washed with a 10 per cent. solution of ammonium nitrate, and subsequently dissolved in ammonia. On evaporating the solution to the original volume, some more silica may precipitate out. This adheres to the sides of the vessel with the molybdate precipitate. It is best, therefore, to place the funnel containing the filter and precipitate in another clean flask and to wash out the first one with dilute ammonia on to the precipitate in the funnel. The ammoniacal solution of the yellow molybdate precipitate is neutralised with hydrochloric acid, a few cubic centimetres of manganese solution added, and then an excess of ammonia. The corked flask is then placed in ice or snow for a quarter of an hour, and subsequently shaken for five

* *Stahl und Eisen*, vol. xvii. pp. 814-815.

minutes. It is then immediately filtered. The precipitate is washed in the usual way, allowed to dry for an hour, and then carefully ignited in a weighed platinum crucible. The results obtained in this way agree remarkably well, and are always somewhat higher than those obtained after allowing to stand for twenty-four hours.

R. W. Mahon* gives the following method for determining the phosphorus within eight minutes after receiving the drillings. Four grammes of drillings are placed in a 16-ounce flask containing 70 cubic centimetres of water and 30 of nitric acid of 1.4 specific gravity, and this is immediately placed over the gas. As soon as all is dissolved, add 3 cubic centimetres of a standard solution of potassium permanganate, and boil till no longer pink. Add 10 cubic centimetres of hydrochloric acid (specific gravity 1.20), boil until clear, remove from gas, wait for a few seconds until the boiling has nearly ceased, and then add a mixture of 50 cubic centimetres of molybdate solution and 10 to 15 cubic centimetres of ammonia (specific gravity 0.90), made ready just before use. Pour into the middle of the flask, not down the side. Twirl the flask in both directions successively, without delay. Shake the open flask for about a quarter of a minute. Filter and wash with cold water. Place the paper and precipitate in the beaker, containing an excess of caustic potash solution, add phenol phthalein, and determine the excess of caustic by the standard acid. The two standard solutions are of the customary strength. The molybdate solution is made according to the following formula:—100 grammes of molybdic acid are dissolved in a mixture of 200 cubic centimetres of ammonia (specific gravity 0.90) and 200 cubic centimetres of water, and the solution filtered into 1250 cubic centimetres of nitric acid (specific gravity 1.20), blowing air through the mixture.

Determination of Sulphur.—L. Campredon† discusses Schulte's work on this subject. With regard to the question as to whether the action of hydrochloric acid on metals is complete, and as to whether the whole of the sulphur passes away in the gaseous form, the author refers to various papers which have appeared as to this point, and have shown that the residues left after the action of dilute hydrochloric acid in iron are practically free from sulphur. It has been shown, however, that the iron dissolves the more readily when, instead of hydrochloric acid by itself, use is made of a mixture of two parts of dilute

* *Journal of the American Chemical Society*, vol. xix. pp. 792-795.

† *Stahl und Eisen*, vol. xvii. pp. 486-489; one illustration.

hydrochloric acid (consisting of one part of the concentrated acid to two of water) with one part of dilute sulphuric acid, this latter being made by mixing one volume of the concentrated acid with four volumes of water. Considering next the question whether the whole of the sulphur escapes as sulphuretted hydrogen, and is absorbed or oxidised by the cadmium solution, bromo-hydrochloric acid, ammoniacal hydrogen peroxide, &c., employed for this purpose, the author observes that when dilute hydrochloric acid is used to dissolve the iron, only a portion of the sulphur escapes as sulphuretted hydrogen, the remainder passing off in the form of an organic compound which is neither absorbed nor oxidised. As Rollet has shown, it is necessary to heat the escaping gas to redness, when it suffers decomposition, and the whole of the sulphur passes off as hydrogen sulphide. An arrangement is illustrated by which such a solution and subsequent heating of the escaping gases can be effected. It was shown in 1895 by Phillips that the volatile sulphur compound, which is neither oxidised by bromo-hydrochloric acid nor absorbed by the solution of some metallic salt, has the composition $(\text{CH}_3)_2\text{S}$. The author gives the results of twenty-two tests of various kinds of iron and iron alloys with and without the heating of the gases after solution, to show the necessity for such treatment. Frequently more than one half the sulphur was in the form of the methyl sulphide referred to above. The error is by no means constant, and it varies with the nature of the metal.

Remarking on this paper of Campredon's, W. Schulte * observes that quite recently he has examined twenty-eight different samples of iron, and in every instance he found that when iron is dissolved in dilute hydrochloric acid the sulphur escapes in two forms, the larger portion as hydrogen sulphide, and the remainder as a gas which was not affected either by bromo-hydrochloric acid, ammoniacal hydrogen peroxide, or cadmium acetate. Whether, however, the latter gas was methyl sulphide was not determined. The apparatus used is illustrated, and the method fully described. Twenty-four results are given to show its accuracy. The apparatus used consists of a large-sized apparatus for the production of the carbon dioxide; next, a large flask of about half-a-litre capacity, suitable for the solution of 10 grammes of iron, provided with a three-holed indiarubber stopper, and a thistle funnel and stopcock. After this comes a sloping cooling tube to allow the condensed products to flow back into the dissolving flask, and this is followed by another flask of peculiar shape containing ammoniacal hydrogen peroxide or

* *Stahl und Eisen*, vol. xvii, pp. 489-493.

a solution of cadmium acetate. The gases escaping from this pass through a glass tube heated in a Glaser combustion furnace with seven burners, and then through another absorption flask containing a retaining solution as before. The apparatus having been put together, the combustion furnace is lit, and some 10 grammes of the iron under determination is placed in the dissolving flask. In the two absorption flasks a solution of cadmium acetate is then placed. This is obtained either by dissolving 25 grammes of cadmium acetate, or 5 grammes of cadmium acetate and 20 grammes of zinc acetate, with 200 cubic centimetres of glacial acetic acid and distilled water, on the water-bath, using heat. After the solution has cooled it is diluted to 1 litre with water, and then filtered. A rapid current of carbon dioxide is then passed through the whole apparatus, about 2 or 3 litres in the course of five minutes. The evolution of the carbon dioxide is then allowed to cease, and about 200 cubic centimetres of dilute hydrochloric acid is placed upon the iron under examination. This dilute acid is made by mixing one part by volume of hydrochloric acid of 1.19 specific gravity with two parts by volume of water. Each gramme of iron requires 20 cubic centimetres of this dilute acid for its solution. In the use of the apparatus various precautions are taken which the author mentions. The solution of the iron is effected by the aid of heat, and care is taken that the glass tube in the combustion furnace is kept at a dull red heat for a length of about 6 or 8 inches. When the solution is complete a further current of carbon dioxide is passed through the apparatus. Immediately after separating the absorption flasks, into each of these is run 5 cubic centimetres of an acid copper solution, obtained by dissolving 120 grammes of copper sulphate in 800 cubic centimetres of water and 120 of concentrated sulphuric acid. After cooling this solution it is diluted to 1 litre and filtered. On the addition of the copper sulphate solution the cadmium sulphide changes immediately into black copper sulphide, giving the mixture a greyish appearance, though copper sulphate is present in the solution in excess. The acetates, too, have been converted into sulphates. Had copper sulphate been used direct in the absorption flasks, copper phosphide would have been formed, and the result would consequently have been too high. By using zinc or cadmium acetate, however, this is avoided, as phosphoretted hydrogen is without action on them. The copper sulphide precipitates are then filtered off, converted into oxide by ignition, and then by multiplying its weight by 0.4041 the weight of the sulphur results that was set free on the solution of the iron. In

the results which the author tabulates, no constant relation is found to exist between the two forms of sulphur, though, generally speaking, it would seem that the higher the percentage of carbon in the metal, the higher was the percentage of that form of sulphur which was not determinable except after heating.

Determination of Nickel.—O. Ducru* describes the electrolytic separation of iron from cobalt and nickel, and the determination of nickel in steel by this method. The author states that although when the iron in the iron-nickel solution is thrown down by an excess of ammonia, some of the nickel passes into the precipitate, yet that, if the ammoniacal solution with its suspended precipitate is subjected to electrolysis, the whole of the nickel is precipitated on the cathode. The separation is not absolutely accurate, as small quantities of iron are nearly always deposited on the cathode with the nickel. With proper precautions the quantity so precipitated varies from 1 to 2 milligrammes if the total quantity of iron present is 400 or 500 milligrammes. For accurate work it is therefore necessary to make a correction which may be easily done by dissolving in hydrochloric acid, oxidising, and precipitating by ammonia. A nitric acid solution and a hydrochloric acid solution give less satisfactory results. Good results may, however, be obtained with a sulphuric acid solution to which ammonium sulphate has been added. The method is as follows:—The solution containing the nickel and the iron is evaporated with a slight excess of sulphuric acid, taken up again with as little water as possible, 5 to 10 grammes of ammonium sulphate added, and heated until a clear solution results. This is transferred to the crucible of a Riche apparatus, into which from 60 to 70 cubic centimetres of ammonia had been placed. Then the whole is electrolysed; after four hours, provided a current of suitable strength has been used, the whole of the nickel will have been precipitated. The method has been checked by standard solutions of iron and nickel. For the determination of nickel in steel the author treats from 250 to 300 milligrammes of the metal in a porcelain dish with nitro-hydrochloric acid. When the reaction ceases, one cubic centimetre of sulphuric acid is added and the whole evaporated until white fumes appear. The operation is then completed in the manner above described. It is found unnecessary to filter off the silica and carbon. The presence of the small quantities of manganese and phosphorus that are in the

* *Chemiker Zeitung*, vol. xxi. p. 780.

steel do not interfere with the method, and neither does the presence of chromium, but traces of manganese are nearly always to be found on the cathode with the iron. The author points out, too, that this precipitated iron always exists there in two separate forms. If the metal deposited on the cathode is dissolved in hot dilute hydrochloric acid, a solution is obtained which contains traces of iron. A slight black residue is also noticeable, which is not dissolved by hydrochloric acid even when concentrated. It passes into solution, however, when some nitric acid is added and the mixture boiled. This solution in nitro-hydrochloric acid gives the reactions of ferric salts.

The presence of even small quantities of chromic acid in the ammoniacal solution hinders the precipitation of the metal. J. Spüller* recommends the following colorimetric method for the determination of nickel in nickel-steel. For each 2 grammes of the steel sample and of the standard steel, 60 cubic centimetres of nitric acid of 1.2 specific gravity is employed. The metal is dissolved in this in a 250 cubic-centimetre flask, and the nitrous fumes driven off by boiling. After cooling, the iron is precipitated by zinc oxide, the flask filled up to the mark, mixed, allowed to settle, and then filtered. The colour comparison is effected by the aid of an arrangement similar to that employed for the Eggertz carbon test. For nickel steels containing 1 to 7 per cent. of nickel, three standard steels with respectively 1, 3, and 5 per cent. of nickel are adequate. When less than 1 per cent. of nickel is present this method is not applicable.

Determination of Tungsten in Ferro-Tungstates.—According to H. Wdowiszewski,† about one gramme of the sample is fused with six times its weight of a mixture of two parts of dry borax and three parts of potassium sodium carbonate; the fused mass on being exhausted with boiling water leaves the ferric oxide undissolved. The filtrate is mixed with excess of hydrochloric acid, evaporated to dryness, and the residue treated with dilute hydrochloric acid, which leaves the tungstic and silicic acids undissolved. The tungstic acid is then dissolved in ammonia, and reprecipitated by adding hydrochloric acid.

Determination of Tin in Tin Plate.—H. Mastbaum‡ describes a rapid method for this. About 25 grammes of the broken-down tin-

* *Chemiker Zeitung*, vol. xxi. pp. 243-244.

† *Chemisches Centralblatt*, 1896, i. 770; *Journal of the Chemical Society*, vol. lxxii. p. 351.

‡ *Zeitschrift für angewandte Chemie*, 1897, p. 330; *Stahl und Eisen*, vol. xvii. p. 594.

plate are treated at the boil several times in succession for periods of five minutes, with quantities, each amounting to 50 cubic centimetres, of hydrochloric acid of 10 per cent. strength, the stanniferous solutions being poured off into a quarter-litre flask. Usually two such boilings are sufficient, and never more than four are necessary. It is easy to see from the appearance of the strips when they have been properly stripped. The solution is colourless and need not be filtered. The flask is thus filled up to the mark, and 50 cubic centimetres of the solution put in a hundred cubic centimetre flask, ammonia added until stannous hydrate begins to precipitate, and then 10 cubic centimetres of strongly yellow ammonium sulphide. The whole is well shaken, and the flask then filled up to the mark. Fifty cubic centimetres of the filtrate, representing 2.5 grammes of the original material, are diluted with water in an Erlenmeyer flask, and acetic acid is added until the tin sulphide has been completely precipitated. This is allowed to settle properly, and it is best to let it stand over-night. It is then brought on to a filter, using ammonium acetate. No copper being present, it is possible to use this ammonium sulphide instead of potassium sulphide, and therefore washing the precipitate on the filter is unnecessary. The precipitate is well dried, placed with the filter in a porcelain crucible, and ignited until quite white, some ammonium carbonate being added during the ignition. Instead of precipitating the tin in the 50 cubic centimetres with ammonium sulphide, the solution may be evaporated direct, no silica being present.

II.—ANALYSIS OF IRON ORE.

Determination of Iron.—H. P. Cady* and A. P. Rüdiger describe a modification of the permanganate method. They conclude that it ought to be possible to titrate iron with permanganate in the presence of hydrochloric acid if an excess of mercuric sulphate be added to the solution. A number of experiments to test this conclusion were made with very satisfactory results.

Analysis of Chrome Ore.—A. G. McKenna,† for the analysis of chrome ore, mixes one gramme of the finely ground and dried sample

* *Journal of the American Chemical Society*, vol. xix. pp. 575-581.

† *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xiii. pp. 180-182.

with 3 or 4 grammes of sodium peroxide in a 20 cubic centimetre nickel crucible, fuses the mixture, and maintains the liquid mass at a low red heat for one minute. After cooling, the mass is extracted with hot water and the residue filtered off. This residue containing the iron is ignited in a platinum crucible, fused with potassium bisulphate, dissolved in dilute sulphuric acid, reduced by filtration through zinc, and titrated with permanganate. The filtrate in a 500 cubic centimetre flask is boiled for ten minutes to remove the peroxide, cooled and acidified with a large excess of sulphuric acid, 1 in 4. It is then diluted to 800 cubic centimetres and 70 cubic centimetres of ferrous sulphate solution, containing 10 grammes of iron in the ferrous state per litre, is added. The excess of ferrous sulphate is determined by titration with permanganate, of which one cubic centimetre is equivalent to one cubic centimetre of the ferrous sulphate solution. Silica, lime, and magnesia are determined on half a gramme of the sample fused as before.

Determination of Silica.—J. S. de Benneville* calls attention to the observations of Dufty and others on the action of ammonia on silica in the separation of silica and tungstic oxide by that reagent. Some silica is dissolved even in the cold, and if ignition is carried too far, the tungstic oxide is rendered insoluble. The total oxide should be weighed, and the silica volatilised by treatment with hydrofluoric acid, with the addition of a little sulphuric acid.

Determination of Phosphorus.—C. T. Mixer and H. W. Du-bois† give some notes on the determination of insoluble phosphorus in iron ores. The white residue left after extraction of the ore with hydrochloric acid frequently contains phosphorus, which is not dissolved by the acid on further boiling. After some successful experiments, in which the ore was ignited with sodium carbonate, magnesia, &c., the authors found that it was quite sufficient to simply ignite the residue, after which hydrochloric acid would dissolve the remaining phosphorus. The process used is as follows:—About $1\frac{1}{2}$ gramme of ore is dissolved with 25 cubic centimetres of hydrochloric acid of 1.1 specific gravity, the solution evaporated to syrup, diluted and filtered. The filter-paper and residue are ignited in a platinum crucible, the ash

* *Journal of the American Chemical Society*, vol. xix. pp. 377-379.

† *Transactions of the American Institute of Mining Engineers*, Chicago Meeting, 1897 (advance proof); *Journal of the Franklin Institute*, vol. cxliv. pp. 137-138.

being broken up and re-ignited at a red heat for a couple of minutes, when it is placed in a beaker for solution. Water and a few drops of nitric or hydrochloric acid are used, and it is boiled gently for five minutes and filtered into the main solution, or, preferably, the phosphorus is determined separately, to avoid rendering the solution too dilute. The solution is neutralised with ammonia and precipitated as ammonium phospho-molybdate, which is titrated according to Handy's modification of the sodium hydroxide method. Experiments showed that the insoluble phosphorus was probably combined with alumina, but the reason of its solubility after ignition is not clear.

It is pointed out by Woy* that the ordinary molybdate method for the determination of phosphoric acid is not under all conditions satisfactory. He has therefore made a series of investigations relating to various points in the process, and he describes a modified method, with a view more directly to the analysis of manures, raw phosphates, &c., but it is also applicable to the citrate solution of basic slag.

Determination of Phosphoric Acid in Basic Slag.—O. Böttcher† observes that he has already pointed out that it is not necessary to employ the molybdate method for the determination of the soluble phosphoric acid in basic slag, but that correct results may be obtained by the citrate method properly carried out. The solution having been effected by the Wagner method, 50 cubic centimetres of it are taken, mixed with 50 cubic centimetres of ordinary citrate solution and 25 of magnesia mixture, and then shaken at once for half-an-hour and filtered as rapidly as possible through a Gooch crucible. It has been found, too, that it is absolutely necessary to use a freshly-prepared citrate solution. If allowed to stand for any length of time, the results are inaccurate. Silica in considerable quantities is deposited if the citrate solution has been standing for twenty-four hours. The actual method is as follows:—5 grammes of the basic slag in its raw state as sold is placed in a half-litre flask, which is then filled up to the mark with a dilute ammonium citrate solution, as recommended by Wagner, the temperature of this solution being 17.5° C. The flask is then closed by an indiarubber stopper, and transferred immediately for half-an-hour to a shaking apparatus making thirty to forty rotations in the minute. The mixture is then filtered immediately, either by transferring the whole to a large filter or by first decanting. Fifty cubic centimetres of the solution are mixed as soon as is possible, and not

* *Chemiker Zeitung*, vol. xxi. pp. 441-443.

† *Ibid.*, pp. 783-784.

later at the outside than the same day, with an equal quantity of the ordinary citrate solution (Maercker) and 25 cubic centimetres of magnesia mixture (Maercker), then immediately shaken in the shaking apparatus for half-an-hour, filtered as soon as possible through a Gooch crucible, dried, ignited for three or four minutes in a Rössler furnace, and weighed after cooling in a desiccator.

M. Passon * attempts, partly successfully, to calculate the amount of citrate soluble phosphoric acid from the total citrate soluble matter, the insoluble portion of the basic slags being collected on a weighed filter and weighed. Further experiments will, however, have to be made.

III.—ANALYSES OF FUEL.

Use of the X-Rays in the Laboratory.—W. Thörner † shows how the X-rays may be used in analytical work, and gives a number of illustrations, describing also the apparatus used. Starting with the knowledge that most minerals are more or less opaque to these rays, but that coals are transparent, he submitted a number of these latter to examination in this way, with a view to ascertain whether the presence of other minerals in the coal could be detected. This was found to be the case, the photographs taken showing the entangled minerals from Piesberg anthracite and Langenbeck bituminous coal with the greatest clearness.

Coke Analysis.—W. F. Keating Stock ‡ describes the sampling and analysis of coke and the valuation of coal for coking purposes.

Analysis of Bitumen.—H. Endemann § describes the analysis of asphalt, and a paper on the same subject has been published by S. F. and H. E. Peckham. ||

* *Zeitschrift für angewandte Chemie*, 1897, pp. 82-84.

† *Chemiker Zeitung*, vol. xxi. pp. 429-436.

‡ *Journal of the Society of Chemical Industry*, vol. xvi. pp. 304-309, 408.

§ *Ibid.*, vol. xvi. pp. 121-126.

Ibid., pp. 424-427.

IV.—GAS ANALYSIS.

Improvement in Gas Analysis.—H. Alexander* describes various improvements in methods for gas analysis and control. Among these is an apparatus by W. Hempel which is based on the property of a flame to increase its size in accordance with the percentage of oxygen in a gas mixture. Several improved gas burettes are mentioned, as well as various practical modifications in such apparatus. A simplified modification of the well-known Orsat apparatus is referred to. A method of avoiding the errors relating to the corrections necessary for temperature and pressure has been devised by C. Than. The same principle is made use of as has been employed by G. Lunge and C. Winkler in the apparatus devised by them, and in which without any observation of the temperature and height of the barometer, a rapid reduction of the gas volumes to the normal is rendered possible. The volume is calculated which a certain number of cubic centimetres of a gas—for instance, air—would occupy at the normal temperature and pressure, and exactly this volume is enclosed by mercury in a calibrated tube. This gas volume changes its volume in exactly the same way as the gas under examination, so that the normal volume of the latter can be readily calculated as soon as the mercury in the two tubes has been brought to the same level. The apparatus of v. Than is more complicated, but it admits apparently of a very high degree of accuracy.

For the examination of air containing fire-damp several new forms of apparatus have been devised. The Grisoumeter devised by Coquillion has been improved by him, and it is stated that it will now admit of a determination of fire-damp in four or five minutes, accurate to 0.01 per cent. The combustion and measuring vessels have been water-jacketed, and the measuring vessel has been modified to admit of more accurate readings. An apparatus based on the same principle of construction as that of Coquillion has been described by Reichenberg, but the author does not consider it possesses any advantage over the other, and in his opinion none of the various suggested apparatus based on the Coquillion principle is satisfactory for practical use in fire-damp determinations. The percentages of fire-damp that have to be determined are usually so small that gas-burettes are unsuitable. Jeller has devised a modification to avoid the difficulties

* *Chemiker Zeitung*, vol. xxi. pp. 553-557.

connected with these. He measures the changes in pressure which result by the consecutive removal of the several constituents of the gas-mixture. This is effected by the aid of a column of water. The height of the water-column being 10,000 millimetres, a diminution of 1 millimetre in the pressure corresponds to a diminution of 0.01 per cent. in the volume—that is to say, to 0.01 per cent. of the constituent removed. For the quantitative determination of hydrogen, E. D. Campbell and E. B. Hart employ a 1 per cent. solution of palladium chloride as suggested by Phillips. The results are stated to be very accurate, but the author does not see any advantage in this method over the ordinary oxygen method with slightly-heated palladium asbestos or a Drehschmidt platinum capillary. A number of other methods relating to the determination of the other constituents of gas mixtures are briefly passed in review. F. Fritsche has devised a method for the separation of ethylene from the other heavy hydrocarbons. This method consists in the use of concentrated sulphuric acid, which retains all the ethylene, and subsequently on distillation with water yields a quantity of alcohol which corresponds to that of the ethylene that had been absorbed. The percentage of alcohol in the distillate is obtained by the determination of its weight and specific gravity. Ethylene has been found by another observer, together with the other gaseous unsaturated hydrocarbons, to be slowly oxidised in moist air. This will account for the large percentages of nitrogen occasionally noticed—this having had its source in air—the oxygen of which has disappeared owing to the oxidation by it of the gases referred to.

Experiments made at the Saarbrücken laboratory have shown that at the twenty-three collieries examined, the combustible gas escaping with the waste air used for ventilation amounts to as much as 62,426,000 cubic metres (2,204,574,190 cubic feet). This quantity of gas possesses a heating effect in excess of that of the whole of the coal mined at these collieries.

An illustration has been published* of an appliance for continuously indicating the percentage of carbon dioxide in flue gases. They are drawn through a filter and a drying tube, and then passed continuously through a globe mounted on one arm of a delicate balance. This method of course is old, but the apparatus appears to be well arranged.

* *American Manufacturer*, vol. ix. pp. 871-872.

STATISTICS.

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I.—UNITED KINGDOM.

Mineral Statistics.—According to the official report of Her Majesty's Inspector of Mines,* the production of coal in the United Kingdom in 1896 amounted to 195,361,260 tons. The production during the previous year was 189,661,362 tons. The total quantity of iron ore raised in 1896 was 13,700,764 tons, of which 7,856,586 tons was obtained from mines under the Coal Mines Regulation Act, 2,237,600 tons from mines under the Metalliferous Mines Act, and 3,606,578 tons from open works.

The production of pig iron in 1896 is officially stated to have been as follows :—

	Tons.
Hæmatite	3,647,972
Ordinary and basic	4,814,976
Spiegeleisen, ferro-manganese, &c.	196,733
Total	8,659,681

The estimate of the British Iron Trade Association was 8,563,209 tons.

* "Mineral Statistics of the United Kingdom." London, 1897.

Manufactured Iron Industry.—The total quantity of puddled bar made in the United Kingdom in 1896 amounted, according to the returns of the British Iron Trade Association,* to 1,214,005 tons, as compared with 1,148,012 tons in the previous year. The total number of puddling furnaces in operation was 1727.

Iron Trade Statistics.—The British Iron Trade Association have issued the following statistics,† showing the production for the first half of 1897 :—

	Tons.
Pig iron	4,401,424
Bessemer steel ingots, acid	736,674
Bessemer steel ingots, basic	260,485
Bessemer steel ingots, total	997,159
Bessemer steel rails	472,223

The production of finished Bessemer steel other than rails was as follows :—

	Tons.
Plates and angles	53,892
Bars, tees, and forgings	166,830
Sleepers	21,810
Blooms and billets	252,670
Castings	7,386

Iron Ore Supplies.—J. T. Smith,‡ Past-President of the Iron and Steel Institute, discusses the iron ore supplies available for the British iron trade. Two problems present themselves, namely: (1) The extent to which the home supplies can be further utilised on a larger scale; and (2) the extent to which other cheap and adequate supplies can be secured. The solution of the first problem will possibly be found partly in the increase of demand for basic steel, which would lead to a larger consumption of the oolitic ores of Cleveland, Lincolnshire, Northampton, Leicestershire, Oxfordshire, and other districts, and also in the possibility of finding increased supplies of such ores workable at a low cost when additional railway facilities are provided. Discussing the second problem, the author gives details of the iron ore resources of Spain, Sweden, Algeria, Greece, Italy, and other countries.

* *Iron and Coal Trades Review*, vol. liv. p. 769.

† *Ibid.*, vol. lv. pp. 585-586, 625.

‡ *Ibid.*, vol. liv. pp. 909-910.

II.—AUSTRALASIA.

Mineral Statistics of New South Wales.—The official statistics of the Colony of New South Wales* show an increase of 170,927 tons of coal in 1896, as compared with the previous year. The average price per ton is given as 5s. 9·06d., being lower than ever it has been before. The export trade is increasing. At the end of 1896 there were ninety-six coal-mines and five shale-mines under inspection, a decrease of three and two respectively as compared with the previous year. The figures for 1896 are as follows, those for 1895 being added for comparison :—

	1896.	1895.
Exports to intercolonial ports, tons	1,371,796	1,196,504
Exports to foreign ports, tons	1,103,111	969,726
Home consumption, tons	1,434,608	1,572,359
Total output, tons	3,909,517	3,738,589
Men employed in coal and shale mines	9,460	9,022
Accidents, fatal	24	10
" non-fatal	62	47
Coke made	26,351	27,630
Shale produced	31,839	59,426

Negotiations are still proceeding with a view of establishing iron ore smelting works in the colony of New South Wales. Some ore is raised for use as flux, and some new deposits have been found. Finished iron made from scrap has been manufactured to the amount of 4721 tons in 1896. No manganese mining is being carried on at present.†

Mineral Statistics of Victoria.—According to the official returns,‡ the quantity of coal raised in 1896 amounted to 226,562 tons. Details are given in the report of numerous borings put down in search of coal. The report also contains a memoir by J. Sterling on systems of mining coal in Victoria.

Mineral Statistics of Western Australia.—According to the official returns,§ the quantity of coal raised during 1896 was 9801 tons. The mines are still in early stages of development.

* *Annual Report of the Department of Mines*, 1896, pp. 40-45, 74-76, 86-95.

† *Ibid.*, p. 50.

‡ *Annual Report of the Secretary for Mines*. Melbourne, 1897, p. 13.

§ *Report of the Department of Mines*, Perth, 1897, p. 21.

Mineral Statistics of Queensland.—According to the official returns,* the quantity of coal raised in 1896 was 377,350 tons. There was also produced 305 tons of manganese ore.

III.—AUSTRIA-HUNGARY.

Mineral Statistics of Austria.—Further details are published as to the Austrian coal and iron trade in 1895.† At the close of this year there were granted in Austria 40,069 land concessions for mining purposes. Of these, 77·08 per cent. relate to coal, and 4·89 to iron ores. In underground colliery workings there were over 800 miles of rails, and about 350 at surface. Details are given as to the machinery in use at the mines for winding and pumping, and other general purposes.

At metallurgical works there were 97 iron blast-furnaces and 25 others, 15 Bessemer converters, 62 cupolas, 108 reverberatories, 141 hot-blast stoves, 72 blast-furnace lifts, and a large number of furnaces of other kinds are mentioned. The works possessed 78 steam blowing engines, of a total of 15,522 horse-power, and 61 others driven by water-power. The different divisions of the Empire are dealt with in detail, the progress made in each of them being mentioned, and a number of colliery and other undertakings referred to at greater length.

Bohemian Brown Coal.—As in previous years, the Aussig-Teplitz Railway Company now publishes statistics relating to the output of the Bohemian brown coal mines in 1896. This was as follows:—

District.	Brown Coal.	Workpeople.
	Metric Tons.	
Falkenau	2,034,496	4,880
Teplitz-Brüx-Komotau	13,262,355	23,293
Totals	15,296,851	28,173

This quantity exceeds by 574,700 tons the output in the previous year. The chief producing mine was that of the Brüx Mining Company, the output of which was 3,700,000 tons.‡

Imports and Exports.—The annual official report§ on the foreign

* *Annual Report of the Under-Secretary for Mines*, Brisbane, 1897, p. 17.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 226-230.

‡ *Ibid.*, p. 423.

§ *Ibid.*, pp. 236-242.

trade of the Austro-Hungarian Customs Union has been issued for the year 1896. The mineral imports and exports were as follows :—

	Imports.	Exports.
	Tons.	Metric Tons.
Brown coal	19,981	7,562,720
Coal	5,175,321	658,367
Coke	491,028	116,607
Manganese ores	7,371	701
Iron ores	107,017	254,389

The increase in the exports of iron ore is noteworthy. Compared with the previous year the increase is 53 per cent. The ore is all absorbed by Germany.

Accidents in Mines and Works.—In the year 1895 * there were in Austria 559 mining and 83 smelting works undertakings in active operation. In mining there were employed 117,177 workpeople, and in the smelting works 8312. Of the total number 125,489, 113,172 were men, 6815 women, the remainder being girls and youths, with the exception of 7 children.

In coal-mining 54,563 were employed, in brown coal mining 45,182, in iron ore mining 4502, and in ironworks 6297, all through totals showing increases over the similar figures for the year 1894. Of the total number, 125,489, no less than 55,019 were employed in Bohemia, 23,314 in Silesia, 14,261 in Styria, and 9184 in Moravia. Next to these comes Galicia with 4049 and Carinthia with 3668.

In 1895 there were 909 accidents in Austrian mines. These included 6 fatal accidents to women, and 203 to men and young people, while the severe accidents numbered 8 among the women and 692 among the remainder. In smelting works there were 4 fatal and 16 severe accidents. These accidents included :—

Mineral.	Accidents.			
	Fatal.		Severe.	
	1895.	1894.	1895.	1894.
Coal	107	276	259	226
Brown coal	80	93	364	314
Iron ore	8	3	18	33

* *Oesterröichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 304-306.

For each fatal accident and for each accident of whatever kind there was raised :—

Mineral.	For each Fatal Accident.		For each Accident, Fatal or Non-Fatal.	
	1895.	1894.	1895.	1894.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Coal	90,866	34,685	26,565	19,069
Brown coal	229,864	186,371	41,417	42,586
Iron ore	173,114	404,912	53,266	36,810

Of the total number of deaths from all causes in mines, 52 were due to fire-damp, and 3 to breathing choke-damp. By falls in the mine 45 were killed and 108 wounded; by accidents connected with the winding, 20 killed and 182 wounded, and by pieces of rock or other substances falling, 29 killed and 120 wounded. In the blasting operations 4 were killed and 26 wounded. Details are also given as to the remainder under a number of different headings.

In 24 cases more than one person was killed at the same time, as compared with 7 in the previous year, though, as will be seen from the totals given above, no accidents involving quite such heavy loss of life was experienced in 1895 as in 1894. The most severe was the dynamite and coal-dust explosion at the Hohenegger pit at Karwin, by which 52 were killed and 16 severely wounded. The next in severity was at the Larischmönich Colliery in Karwin, in which a coal-dust explosion, causing severe injuries to 10 workpeople, was due to an injury to an electric incandescent lamp.

Petroleum in Galicia.—According to the latest statistics, the production of petroleum in Galicia in 1896 amounted to 339,765 tons, or about 2,300,000 barrels. The consumption was as follows :—

	Barrels.
Galician refineries	735,000
Other Austrian refineries	810,000
Hungarian refineries	564,200
Exported	1,800
Total consumption	2,111,000

The following statistics regarding the ozokerite mines of Galicia in 1896 have been published :*—

* *Chemiker Zeitung*, vol. xxi. p. 456.

Number of mines	44
Number of shafts in operation	289
Number of shafts being sunk	32
Number of shafts abandoned	413
Production, in tons	7,210

Mineral Statistics of Bosnia and Herzegovina.—According to official statistics, the mineral production of Bosnia and Herzegovina in 1896 included :—

	Metric Tons.	Value.
		£
Iron ore	23,213	4,961
Chrome ore	442	1,356
Manganese ore	6,821	11,254
Iron pyrites	2,000	1,000
Brown coal	222,724	46,957

The number of persons employed in the mines and smelting works included :—

Coal-mining	838
Iron-mining	163
Ironworks	501

The improvements introduced during the year include the erection of a second blast-furnace for 30 tons of pig iron daily, with two new hot-blast stoves and a compound steam-engine at the Veres Ironworks, as well as the construction of a branch railway, 15 miles in length, from these works to the Podlugovi station of the Bosnian State Railway. A coal-washing plant, with a capacity of 500 tons a day, has been erected at the Zenica Coke Works. At the Kreka Colliery new pumps have been put in, and electrical transmission for working a Rateau fan has been installed.

The output of pig iron in Bosnia and Herzegovina in 1896 amounted to 10,120 tons, an increase of 7551 tons as compared with the output in 1895. Of castings 1039 tons was made, and of open-hearth ingots 3265 tons. In 1895 no open-hearth ingots were made. Of rolled iron the output in 1896 amounted to 5418 tons.*

* *Stahl und Eisen*, vol. xvii. pp. 518-519; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 223-224.

IV.—BELGIUM.

Mineral Statistics.—The mineral statistics of Belgium for the first half of 1897 have been published.* There were 119 collieries in operation, the output being 10,583,250 tons of coal. The production of pig iron amounted to 515,701 tons, that of wrought iron to 238,572 tons, that of steel ingots to 304,744 tons, and that of steel rails to 253,340 tons.

In his annual report, E. Harzé † states that the production of coal in Belgium in 1896 amounted to 21,252,370 tons, and that of pig iron to 959,414 tons, that of wrought iron to 494,032 tons, and that of steel ingots to 598,974 tons.

Detailed reports have also been published of the coal and iron trades of Hainaut, ‡ of Liège, § and of Namur || in 1896.

V.—CANADA.

Mineral Statistics.—In the report of J. Baker, the Minister of Mines of British Columbia, are given the following statistics of production :—

	1895.	1896.
	Tons.	Tons.
Coal	939,654	846,235
Coke	452	615

Coal production has not increased in recent years, and has fluctuated considerably since the maximum of 1,029,097 tons in 1891. The total production up to the end of 1896 is given as 11,248,759 tons.¶

According to the report of the Department of Mines of Nova Scotia for the year ending September 30, 1896, the iron industry is capable of considerable expansion. Besides the mines worked, there are several which were idle last year, and other deposits exist which can be drawn upon when the demand requires it. A large bed of magnetite of good

* *Moniteur des Intérêts Matériels*, vol. xlvii. pp. 2879, 3136.

† *Ibid.*, pp. 3266-3268. ‡ *Ibid.*, p. 3308. § *Ibid.*, p. 2345. || *Ibid.*, p. 2984.

¶ *Engineering and Mining Journal*, vol. lxiii. p. 400.

quality was discovered in Cape Breton during the year, which is well situated for mining and exporting at a moderate cost.

The coal industry is an old one, the records showing that 1668 tons were mined as long ago as 1786, and yearly statements of production have been made from that date up to the present time, 112 years. Nowhere else in America can such statistics be found. The production grew gradually, but very slowly; up to 1850, 180,084 tons were reported. By 1860 the output had grown to 322,593 tons; in 1870, to 568,270 tons; in 1880, to 954,659 tons; in 1890, to 1,786,111 tons; and in 1896 it was 2,047,133 tons.

According to the reports of the Division of Mineral Statistics and Mines of Canada, there were produced in 1896 the following amounts :—

	Tons.
Coal	3,395,807
Coke	45,194
Iron ore	80,019
Manganese ore	11

Metallurgical Education in Canada.—At the recent meeting of the Society for the Promotion of Engineering Education held at Toronto, M. E. Cooley* urged the importance of engineers having some knowledge of metallurgy. The materials most largely used by engineers are cast iron, steel, and bronze, and it is becoming the practice to specify for cast metals with as much care as for wrought metals. And with skilful workmen and an educated foundryman, it is not a difficult matter to obtain castings that will fulfil the requirements of specifications. To accomplish this, the engineering student ought to have a certain amount of training in metallurgy.

VI.—CUBA.

Iron Ore.—Broadly speaking, about 80 per cent. of all the iron ore now imported into the United States comes from Cuba. The amount shipped from Cuba to the United States in 1896 was 409,883 tons, whilst the total supplies of foreign ore brought into the country amounted to 543,241 tons.†

* *Railroad Gazette*, vol. xxix. p. 597.

† *Age of Steel*, vol. lxxxii. No. 9, p. 20.

VII.—*FRANCE.*

Iron Trade Statistics.—The Comité des Forges de France * has published statistics of the French production of iron during the first half of 1897. The out-turn is as follows :—

	Tons.
Pig iron	1,223,638
Wrought iron	405,696
Steel	630,143

The production of steel included 404,923 tons of Bessemer metal, a large portion of which was obtained by the dephosphorisation of phosphoric pig iron by the basic Bessemer process in the departments of Meurthe-et-Moselle, Ardennes, and Saone-et-Loire.

VIII.—*GERMANY.*

Imports and Exports.—The Society of German Iron and Steel Masters has issued complete statistics † of the German iron trade exports and imports for 1896. The leading items are as follows :—

	Imports.	Exports.
	Tons.	Tons.
Iron ore	2,586,705	2,642,294
Pig iron	322,501	140,449
Manufactured iron and steel	82,514	1,273,003

Compared with the statistics of other countries, the imports and exports of pig iron in 1896 bore the following percentage proportion to the production :—

	Imports.	Exports.
Germany	5·3	3·8
Austria-Hungary	13·5	1·1
France	4·8	10·2
Great Britain	0·2	17·1
Belgium	42·6	3·2

In the case of manufactured iron and steel the percentages were as follows :—

* *Bulletin*, No. 1206.

† *Ibid.*, No. 17.

	Imports.	Exports.
Germany	1.4	21.3
Austria-Hungary	6.2	3.7
France	1.5	5.6
Great Britain	5.9	36.7
Belgium	2.3	47.7

The production of pig iron in the various countries in 1896 is stated to have been as follows :—

	Pig Iron in Thousands of Tons.	Number of Inhabitants in Millions.	Production per Head, Lbs.
Germany	6,342	52.2	265
Great Britain	8,700	39.5	490
France	2,334	38.5	133
Austria-Hungary	1,100	45.0	53
Belgium	933	6.5	315
Sweden	475	5.0	210
Italy	10	31.0	6
Russia	1,390	130.0	23
United States	8,623	71.0	270

Production of Basic Steel.—The Society of German Iron and Steel Masters has issued statistics * of the production of basic steel in the German Empire in 1896. The figures are as follows :—

	Tons.
In the converter	3,004,615
In the open-hearth	1,292,832
Total	4,297,447

The corresponding totals for the years 1894 and 1895 were respectively 3,241,272 and 3,539,203 tons.

Brown Coal Production of Germany.—According to Kaestner,† the output of brown coal has increased very rapidly in Germany in recent years, and he gives the following details :—

Year.	Workpeople Employed.	Output.	Value.
		Metric Tons.	£
1880	25,358	12,144,500	1,835,500
1885	28,186	15,355,100	2,019,000
1890	33,161	19,053,000	2,488,500
1895	37,476	24,788,000	2,900,500

* *Bulletin*, No. 11.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. p. 404.

Similar statistics are also given for Prussia and for the Bonn mining district. In Prussia the number of brown coal mines has steadily diminished from 446 in 1880 to 367 in 1895; but the output has rapidly increased, having risen from 9,874,888 tons in 1880 to as much as 20,114,877 in 1895, the workpeople employed having been 19,757 in 1880, and 30,432 in 1895. Similarly, in the Bonn district, while the statistics for 1880 show 53 mines, 884 workpeople, and 159,582 tons output, in 1895 these figures were respectively 36, 1997, and 1,681,584.

Mineral Statistics of Prussia.—According to the official statistics,* there was produced in Prussia in 1896:—

	Metric Tons.
Coal	78,993,655
Brown coal	21,981,201
Asphalt	16,204
Petroleum	1,512
Iron ore	4,053,108
Nickel ore	737
Manganese ore	43,613

The metallurgical production included:—

	Metric Tons.
Pig iron	4,432,569
Direct castings	29,531
Scrap	8,450
Total pig iron	4,470,550

According to the annual report of the Essen Chamber of Commerce, there were employed in 1896 at Krupp's Steelworks 18,728 workmen. This total includes 617 lads of fourteen to sixteen. The total out-turn of finished iron and steel products was 295,424 tons.

Mineral Statistics of Saxony.—According to the official statistics,† the production of coal in the kingdom of Saxony in the year 1896 amounted to 4,536,603 metric tons, and that of brown coal to 1,035,825 tons, the output per miner being 207·9 tons in the collieries and 501·9 tons in the brown coal mines. The production of iron ore amounted to 3499 tons.

Mineral Statistics of Upper Silesia.—According to the statistics published by the Oberschlesischen Berg- und Hüttenmännischen Verein,‡

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. lxxv. No. 1.

† *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1897, p. 74.

‡ *Stahl und Eisen*, vol. xvii. pp. 461-464.

there were produced in Upper Silesia the following quantities of the substances named in 1896 and in the two preceding years:—

	1896.	1895.	1894.
	Metric Tons.	Metric Tons.	Metric Tons.
Coal	19,586,152	18,063,906	17,195,918
Brown iron ore	460,775	467,161	551,720
Clay iron ore	1,048	613	2,472
Iron ores from lead and zinc mines	7,556	7,920	5,808
Coke pig iron	615,419	531,677	513,803
Charcoal pig iron	600	562	719
Castings	53,123	41,968	37,282
Semi-manufactures, weld iron	16,917	9,644	9,565
Semi-manufactures, ingot metal	97,434	71,641	58,181
Manufactures, iron and steel	543,785	520,526	418,838
Coke	1,188,490	1,113,706	1,062,179
Tar and ammonia water from coke-works	80,232	75,847	59,408

The number of workpeople employed at the collieries in Upper Silesia in 1896 amounted to 56,032, the highest total yet reached. The output amounted to 349·6 tons per miner. The average value of the metric ton of coal was 5s. 2½d. Of the total quantity of coal raised, 21·0 per cent. was classed as lump, 26·1 as smalls, and 14 as dust and fine coal. Of the total quantity of coal consumed in Berlin in 1896, 57·12 per cent. was derived from Upper Silesia, and 20·08 per cent. from the United Kingdom, as compared respectively with 61·93 per cent. and 16·15 per cent. in the previous year.

The active iron ore mines numbered 47 in 1896, as compared with 45 in 1895. Coke was made at 14 works; 13 different types of coke-oven were in use. The coke-works produced 1,007,987 tons of lump coke, 89,462 tons of smalls, 91,041 tons of "cinder," and 80,232 tons of by-products.

Pig iron was made at 11 works, possessing 37 blast-furnaces, of which 28 were in blast for 1362 weeks. The consumption of fuel per ton of iron made is steadily diminishing, and amounted to 1·292 ton in 1896. The following table shows the kind of iron made:—

	1896.	1895.	1894.
	Metric Tons.	Metric Tons.	Metric Tons.
Forge pig iron	349,620	326,067	332,451
Foundry pig iron	52,665	37,905	42,110
Basic pig iron	182,032	132,882	106,558
Bessemer pig iron	31,092	33,863	32,207

Of the 53,123 tons of castings mentioned in the general summary as having been made in 1896, 13,817 tons consisted of pipes, and 3408

tons were steel castings from cupolas and open-hearth. The usual details relating to the steelworks are also given. During 1896 the reconstruction of the Gleiwitz blast-furnace plant was completed, and the furnaces were started.¹

The Iron Industry of Siegen.—The following are some details given in connection with the iron industry of Siegen, Germany : *—

Production of Iron Ore.

	1895.	1896.
Active iron ore mines	155	178
Workpeople employed	12,674	13,280
Iron ore raised, metric tons	1,531,991	1,765,509
Total value	£550,539	£772,597
Value per ton, shillings	7·18	8·75

Production of Pig Iron.

	1895.	1896.
Pig iron made, metric tons	455,158	598,291
Value of pig iron made	£1,019,525	£1,539,103
Workpeople employed	1,751	2,105

The blast-furnaces in blast remained in 1896 as in 1895.

The total production of all the mills (forges and puddling furnaces) generally was as follows :—

	1895.	1896.
Total production, metric tons	189,484	234,673
Value of product	£973,615	£1,345,120
Workpeople employed	2,804	3,317

In the iron foundries in this district the out-turn was as follows :—

	1895.	1896.
Total production, metric tons	30,227	35,994
Value of product	£215,846	£279,322
Workpeople employed	958	1,075

* *Stahl und Eisen*, vol. xvii. pp. 555-556.

During the year a syndicating arrangement was come to between the Siegen and the Rhenish-Westphalian Works as to the sale of their outputs.

Mineral Statistics of Bavaria—The statistics of mineral production in Bavaria in 1896 have been issued. They comprise the following :—

	Number of Mines.	Metric Tons.	Number of Miners.
Coal	19	900,080	5,427
Lignite	8	35,934	264
Iron ore	44	161,279	719
Manganese ore	1	70	2
Iron pyrites	2	1,997	45

The metallurgical production included : *—

	Metric Tons.
Pig iron	79,621
Castings	71,006
Bar iron	53,573
Iron wire	243
Steel	101,954

Production of Coal in Prussia.—The following details are given by Kaestner † as to the production of bituminous coal in Prussia :—

Year.	Number of Collieries.	Workpeople Employed.	Output.	Value.
			Metric Tons.	£
1880	392	155,006	42,172,944	10,530,853
1885	375	193,188	52,879,004	13,144,100
1890	342	233,754	64,373,816	23,976,192
1895	260	271,604	72,621,509	23,977,721

According to the official statistics, the production of coal in Prussia during the first half of 1897 amounted to 40,017,473 tons ; 268 collieries were in operation, and 296,412 workmen employed. The production of brown coal during the same period was 11,226,562 tons from 369 mines, 31,709 workmen being employed.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 408-409.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. p. 404.

Coke in the Dortmund Mining District.—The production of coke in the Dortmund mining district of Germany has increased rapidly in recent years, as the following table shows: *—

Year.	Production.	Increase.
	Metric Tons.	Per Cent.
1891	4,388,010	4·8
1892	4,560,984	4·0
1893	4,780,489	4·8
1894	5,398,612	12·9
1895	5,562,503	3·0
1896	6,265,338	12·6

Mining Education in Prussia.—New regulations for the education and examination of candidates for the higher branches of the mining service of the Prussian Government have been promulgated by the Minister of Commerce. The training begins with a year's practical work underground. Of the time devoted to academic studies, eighteen months must be spent at a German University, and two years at a School of Mines. The subsequent technical and business training occupies three years, nine months being spent in Government mines or works, nine months in visiting other mines and works, two months' work under the supervision of a licensed mine surveyor, six months' work in a district mining bureau, and ten months' work in a head mining bureau.†

IX.—GREECE.

Mineral Statistics.—According to official returns, the mineral production of Greece in 1896 comprised 795 tons of manganese ore, 415,987 tons of iron ore, and 1402 tons of chrome ore.

X.—INDIA.

Coal Prospects.—The imports of coal, coke, and patent fuel have been 494,968 tons during the year 1896–97. Imported coal is brought mainly to Bombay and Kurrachee, and there the conditions of trade

* *Stahl und Eisen*, vol. xvii. p. 327.

† *Glückauf*, vol. xxxiii. pp. 777–783; *Colliery Guardian*, vol. lxxiv. p. 696; *Mining Journal*, vol. lxvii. p. 1236.

and industry in the second half of the year were such as to greatly restrict the consumption of coal. The production of coal in India in 1896 amounted to 3,848,013 tons, being in the ratio of about $7\frac{1}{2}$ tons locally produced to one ton imported. This is much the largest ratio as yet known, and it will perhaps hardly be maintained for some years to come; for although the production of Indian coal increases while the importation of coal is gradually dwindling, last year was quite exceptional in its conditions.*

Valuable details of the progress of the various collieries in India are given in Colonel Gracey's last report † on the administration of railways in India.

XI.—ITALY.

Iron Trade Statistics.—The production of steel in Italy in 1896 amounted to 55,000 tons. In 1889 the out-turn was as much as 157,889 tons. Since that date it has gradually decreased.

There are only two steelworks in Italy, the Terni Steelworks, which possesses two large acid Bessemer converters and five open-hearth furnaces, and the Savona Steelworks, with nine Batho furnaces, one of which is acid and the others basic.‡

According to official returns § the mineral production of Italy in 1896 included :—

	Metric Tons.
Brown coal	276,197
Iron ore	203,966
Manganese ore	33,705
Manganiferous iron ore	10,000
Petroleum	2,524

XII.—JAPAN.

Iron Trade Imports.—In Japanese consular reports which have just been issued it is stated || that the whole value of metals imported into Nagasaki in 1896 amounted to £225,629 as compared with only £49,712 in 1895. The value of the locomotives, machinery, and boilers

* *Indian Engineering*, vol. xxii. p. 229.

† *Colliery Guardian*, vol. lxxiv. p. 332.

‡ *Mining Journal*, vol. lxxvii. p. 843.

§ *Rivista del Servizio Minerario nel 1896*.

|| *Birmingham Daily Mail*, October 15, 1897.

imported amounted to £75,910 in 1896, and to but £28,928 in the previous year. The greater part of these came from the United Kingdom. The 1300 miles of cable that has recently been laid between Japan and Formosa was also supplied by the United Kingdom. From other parts of Japan it is stated that one-half the imports are of British origin. It is pointed out, however, that the United States will soon compete, especially in the case of pig iron and iron manufactures.

Coal.—The production of coal in Japan is rapidly developing. In 1875 the output did not exceed 560,000 tons. In 1896 it was more than 3,000,000 tons. Half this amount is consumed in the country, the remainder being exported for navigation purposes.*

XIII.—MEXICO.

Mineral Statistics.—The Mexican Government does not collect any statistics of mineral production within its domain, but the *Engineering and Mining Journal*† reports that the production of coal in the republic in 1896 was 253,104 metric tons, and of coke 27,215 metric tons. The imports of coal were 236,124 metric tons and the exports 75,540 tons, so that the consumption may be estimated at 413,688 metric tons. Of coke there were imported 109,314 tons, and as there were no exports, consumption amounted to 136,529 tons. At the present time by far the largest part of the coal consumption in Mexico is due to the smelting-works and the railways. The factories on the lines of the railways use some, but there are not yet very many of these, while as a domestic fuel coal is scarcely employed in Mexico at all.

XIV.—NATAL.

Iron Trade Statistics.—During 1896 the quantity of coal raised in Natal amounted to 219,665 tons as compared with 162,677 tons in 1895.‡ New collieries are in course of being opened up. There were employed at the collieries 65 white workmen, 941 kaffirs, and 306 East Indians. The coal is not as good as that of the United Kingdom, but is still useful for ships' purposes. The iron-foundries and ship

* *Moniteur des Intérêts Matériels*, vol. xlvii. p. 2856.

† Vol. lxiv. p. 182.

‡ *Stahl und Eisen*, vol. xvii. p. 662.

workshops made progress during the year. The following quantities of materials were imported in the years named :—

	1896.	1895.
	Value, £.	Value, £.
Iron wares	341,677	162,113
Bar iron	28,316	9,977
Plates	11,177*	8,220*
Sheets	11,177*	8,220*
Corrugated sheets	117,395	56,897
Pipes	6,714	3,595
Fencing wire	62,271	32,469
Machines	367,870	52,888

XV.—RUSSIA.

Mineral Statistics.—The last report of the Government Department of Mines gives the following statistics of the mineral production of Russia in 1895 :—

	Tons.
Coal	9,009,000
Naphtha	6,978,000
Pig iron	1,427,000
Wrought iron	415,400
Steel	557,100

The number of workmen employed in the mines and works amounted in 1895 to 460,000, of which number 89,000 worked at gold mines, 7500 in the naphtha industry, and 22,000 at the salt-mines. In the year 1896 the Russian ironworks produced 98,414,000 poods of pig iron, 30,661,000 poods of wrought iron, and 42,596,000 poods of steel.

F. J. Guyon † discusses the industrial awakening of the Russian Empire, and briefly describes the recent advance and present state of coal and iron mining and manufacture in that country.

Coal.—M. Verstraete, of the French Consular Service, has published a memoir on the present condition of Russian trade. Coal, which has been hitherto worked chiefly in the Donetz basin and in Poland, has been discovered in enormous quantities in Siberia. Moreover, thick beds of excellent coal occur in the Ural in association with rich iron ores. Russia in 1880 raised 3,296,000 tons of coal and imported

* As in original.

† *Engineering Magazine*, vol. xiv. pp. 64-69.

1,870,000 tons. In 1894 the production was 8,660,000 tons, and the imports fell to 1,720,000 tons. Apart from this considerable increase in coal consumption, it is evident that Russia has a brilliant industrial future when it is remembered that the coal consumption per head of population is fifty times greater in England, forty times greater in Belgium, and twenty times greater in France.

In the Government of the Don Cossacks, the production of anthracite during 1896 amounted to 47,918,698 poods, and of coal to 80,862,768 poods. The total increase of the out-turn over the previous year was 9,893,277 poods.*

E. Davidson † gives a statistical account of the mineral resources of Russia, giving quotations from a work by W. J. Kowalewski prepared for the Nijni-Novgorod Exhibition. The latest statistics he gives refer to the year 1894.

The Cost of Smelting Pig Iron in the South of Russia.—An approximate estimate of the cost of producing iron in the South of Russia has been published.‡ As the ironworks of this region employ ore from one locality and fuel from another, there is a considerable difference between the cost of the raw materials at the mines and at the works. Respecting the cost at the mines, the chief works rent iron mines at the Krivoi Rog. The royalty paid to the proprietors in some cases is as much as $1\frac{1}{2}$ copeck per pood, § but on the average may be taken at 1 copeck per pood. The cost of raising the ore is estimated at $1\frac{1}{2}$ copeck per pood, so that the actual cost at the mines will be $2\frac{1}{2}$ copecks, or delivered at the railway $3\frac{1}{2}$ to 4 copecks. The market price of the ore varies between 5 and 6 copecks. The cost of coke produced at pit's mouth is as follows:—

	Copecks.
Per 1 pood of coke, $1\frac{1}{2}$ pood of coal, at 5 copecks	7.50
Wages, &c.	1.50
Standing charges	1.75
Total	10.75

or about 11 copecks, while the market price of coke on the spot varies between $14\frac{1}{2}$ and 15 copecks per pood. The Krivoi Rog ore requires a

* *Gorno-Zavodskii-Listok*, May 15, 1897, through the *Revue Universelle des Mines*, vol. xxxix. pp. 82-84.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlv. pp. 90-129.

‡ *Vistnik Finansoff* (11th April 1897).

§ 1 rouble=100 copecks=25½d. ; 1 pood=36.113 lbs.

considerable amount of flux, chiefly limestone. There are no data regarding the cost of limestone at the quarries. After discussing the economical position of the chief works and the railway freights for the raw materials, it is concluded that the cost of pig iron per pood at the works should be—

	Krivoi Rog Ore only.	Krivoi Rog Ore, together with One- third of Poor Ore.
	Copecks.	Copecks.
Ore	9·60	17·29
Flux	3·00	2·00
Coke	23·37	11·82
Coal	0·60	0·25
Labour and standing charges .	8·00	8·00
Totals	44·57	39·37

or from 40 to 45 and from 35 to 40 copecks per pood. Foundry pig-iron will be 2 to 3 copecks dearer. It is also estimated that the cost of manufacturing Bessemer rails will be 90 to 95 for the works using Krivoi Rog ore only, and 80 to 85 for those smelting mixed ores; of open-hearth rails, the same; of puddled iron, 1 rouble 35 copecks and 1 rouble 20 copecks; of sheet iron, 1 rouble 40 copecks and 1 rouble 25 copecks.

A comparison is then made between the above estimated cost of production and of the market prices. Thus the market price of pig iron is given at 60 to 65 copecks per pood, a difference of nearly 50 per cent. above the cost of production. The dividends paid by the works in 1895-96 are given: the Hughes Works, 100 per cent.; the Briansk Works, 30 per cent.; the Dneiprovsk Works, 40 per cent.; and the lately erected Drougeoffsky Works, 6 per cent.

The Iron Industry.—A. Radzig* observes that at the end of the past century the production of pig iron in Russia considerably exceeded that of Great Britain. The reason why the latter has since made such relatively enormous progress lies in the fact that even in the last century the use of coal, instead of charcoal, was introduced in Great Britain, while up to recent times in Russia this had not been done to any large extent. In the Urals the iron industry dates from the beginning of the seventeenth century. The first ironworks there were erected by the State. In Central Russia the iron industry developed very slowly in a

* *Stahl und Eisen*, vol. xvii. pp. 538-543.

number of districts, which the author names. In that of Olonetz the first mining for iron ore occurred in the year 1670. In the year 1797, in the Ekaterinoslav government, unsuccessful attempts were made to introduce the use of mineral fuel in iron smelting, and a similar want of success was experienced with the use of anthracite at the works founded at Kertsch in 1848. In the year 1841 the imports of pig iron and castings by sea into Russia were entirely forbidden, and on the land frontiers high duties were imposed. The results were, however, very unsatisfactory, and the home industries suffered. Comparing the progress made in the United Kingdom and in Russia in the earlier period of this century, the author gives the following table showing the production of pig iron in the two countries :—

Year.	United Kingdom.		Russia.	
	Production.	Increase as compared with 1823.	Production.	Increase as compared with 1823.
	Tons.	Per Cent.	Tons.	Per Cent.
1823	430,745	...	149,255	...
1830	681,441	58	182,948	23
1840	1,433,832	235	185,618	24
1850	2,248,155	422	227,551	52
1857	3,731,331	766	278,460	87

It will be seen, therefore, that the protective duties that had been imposed were unable to double the Russian out-turn, while in the same time that of the United Kingdom had risen to eight times its former quantity. The reason of this slow progress in Russia must be attributed to the fact that the protective duties enabled the Ural works to retain their old methods of manufacture. After 1857 the protective duties were diminished. In 1860 the out-turn of pig iron in the whole of Russia was 320,753 tons, and in 1876, 416,838 tons. Since that date the duties have been again largely increased, but the methods in use have improved as well, and the out-turn has been as follows :—

Year.	Pig Iron Production.	
	Metric Tons.	
1877	.	377,346
1880	.	427,370
1885	.	504,635
1890	.	904,372
1895	.	1,454,298

The output of Southern Russia during this period has increased from 23,980 tons in 1877 to 550,401 tons in 1895. From 1877 to 1884 the

duty on pig iron was five copecks the pood, and during this period the production increased 20 per cent. From 1887 to 1891 the duty was as much as twenty-five copecks the pood, and the increase in production during this term was as much as 65 per cent.

Details are given as to the iron trade imports into Russia for the years 1857-76, and then in another table is shown the number of blast-furnaces and their production in the Urals, Poland, and South Russia for each of the years 1882-93:—

Year.	Urals.		Poland.		South Russia.	
	Blast-Furnaces.	Average Annual Capacity.	Blast-Furnaces.	Average Annual Capacity.	Blast-Furnaces.	Average Annual Capacity.
1882	103	Tons. 2936	31	Tons. 1383	3	Tons. 6,424*
1890	107	4242	30	4242	9	24,184
1893	113	4459	29	5690	13	25,035

The author points out that in 1894 the average annual out-turn per blast-furnace was in the United Kingdom 23,210 tons, about the same as that in South Russia; in Belgium the average yield was 25,880 tons, and in the United States 49,140 tons per furnace.

Details are next given as to the number of workpeople employed, and the number of water-wheels, turbines, and steam-engines used for power. Details as to the production of iron and steel up to 1893 are also shown, together with others relating to the consumption.

XVI.—SOUTH AFRICAN REPUBLIC.

Coal Production.—The report of the State Mining Engineer † gives the total tonnage of coal shipped from all the Transvaal mines in 1896 at 1,471,189 tons, against 1,152,206 tons in 1895, showing an increase of 318,983 tons. The total reported sold in 1896 was 1,437,297 tons, of which 1,207,700 tons were classed as lump, 225,235 tons as nut, and 362 tons as smalls. The *South African Mining Journal* says that the collieries generally do not report the quantity of waste coal or slack. The coal hauled by districts was as follows:—Boksburg, 1,165,557 tons; Heidelberg, 178,093 tons; Middelburg, 69,164 tons; Lydenburg, 23,422;

* 9757 in original.

† *Engineering and Mining Journal*, vol. lxiii. p. 435.

Potchefstroom, Pretoria, and Standerton, 34,953 tons. The total number of persons employed was 6088, of whom 443 were white men and 5645 natives. Of these, 160 white men and 3526 natives, 3686 in all, were employed underground; 283 white men and 2119 natives, 2402 in all, were at work on the surface. The yearly average production per man at work on the surface was 242 tons; per man at work underground, 399 tons.

XVII.—SPAIN.

Mineral Statistics.—The official Spanish mineral statistics* have been issued for the year 1896. Altogether there were in operation 1806 mines and 661 demasias, which afforded employment to 53,674 men, 2107 women, and 7187 boys. There were 622 steam-engines with an aggregate horse-power of 18,235. The total amount of mineral produced is valued at 108,221,970 francs. The following were the quantities of the principal minerals raised:—

	Metric Tons.
Iron ore	6,762,582
Manganese	38,265
Coal	1,852,947

The metallurgical production included—

	Metric Tons.
Pig iron	100,786
Wrought iron	53,793
Steel	68,126
Coal briquettes	343,432
Coke	288,523

Among the events in 1896 worthy of mention were the erection of a factory for lignite briquettes in Alava, the introduction of compressed air rock-drills in Badajoz and Guadalajara, the introduction of electro-motors at a hydraulic cement works in Guipuzcoa, the discovery of rich iron ore in Granada, and the construction of special kilns for calcining spathic iron ore in Vizcaya.

The *Echo des Mines* points out the great increase in the production of steel in Spain in 1896. There are now two large Spanish steelworks producing Bessemer steel, and two others producing open-hearth steel. The Altos Hornos works at Bilbao possess two 9 to 10-ton Bessemer converters, an 11-ton open-hearth furnace, and 14 puddling furnaces. The Vizcaya works at Bilbao possess three 5-ton Robert converters and

* *Revista Minera*, vol. xlviii. pp. 306-308.

four open-hearth furnaces, two acid and two basic of 12 tons capacity each, together with four puddling furnaces. The Duro Company, Asturias, works with three open-hearth furnaces, and 20 puddling furnaces, whilst the Mieres works possess one large open-hearth furnace.

Iron Trade Statistics of Bilbao.—The production of coal and coke in the Asturias has been as follows in the years mentioned :*—

	Coal.	Coke.
	Metric Tons.	Metric Tons.
1895	1,008,769	131,090
1896	1,122,700	150,000

The total production of coal in Spain amounted in 1895 to 1,739,075 tons, and in 1896 to 1,830,771 tons, but, with the exception of the production of Asturia, this additional output, on account of the transport costs, is of no importance to the port of Bilbao. There were imported into Bilbao the following quantities in the years named :—

From	1895.		1896.	
	Coal.	Coke.	Coal.	Coke.
	Tons.	Tons.	Tons.	Tons.
United Kingdom	348,721	70,886	373,818	82,149
Germany	100	7,839	...	17,152

The imports of coal and coke from Germany have gradually diminished, and since the past autumn have entirely ceased. The exports of iron ore from Bilbao have been as follows :—

To	1895.	1896.
	Tons.	Tons.
United Kingdom	3,171,902	3,429,008
Netherlands	609,619	805,176
France	292,530	329,138
Belgium	150,320	130,521
Germany	3,243	5,229
United States	17,128	45,432
Italy . . . . .	...	1,810
Totals	4,244,742	4,746,314

* *Deutsches Handels-Archiv*, July 1897.

That exported to the Netherlands is subsequently forwarded to Germany. The ore exported from ports lying to the west of Bilbao amounted in 1895 to 287,000 tons, and in 1896 to 626,300 tons.

The active demand that has sprung up for the calcined spathic ore has led to the erection of further calciners, which now number seventeen and have an annual out-turn of about 155,000 tons.

The production of pig iron at the three blast-furnace plants at Bilbao has been as follows:—

Year.	Sociedad Vizcaya.	Sociedad Altos Hornos.	J. Martinez de las Rivas.
	Tons.	Tons.	Tons.
1890	86,500	...	55,450
1891	107,515	78,300	38,616
1892	102,818	60,152	17,430
1893	99,127	92,309	20,384
1894	101,411	92,079	24,024
1895	73,142	80,300	25,922
1896	90,015	80,319	36,403

The total production therefore amounted to 179,364 tons in 1895 and to 206,737 tons in 1896.

The exports of pig iron have steadily diminished. In 1891 they amounted to 96,109 tons, and in 1896 to only 20,018 tons. The exports of finished products is still unimportant, and amounted in 1896 to 1753 tons, of which 1672 tons was for Cuba.

XVIII.—*SWEDEN.*

Mineral Statistics.—The mineral and metallurgical production * of Sweden in 1896 included:—

	Metric Tons.
Iron ore	2,039,019
Manganese ore	2,056
Coal	225,848
Fireclay	120,426
Graphite	13,946
Pig iron	494,418
Blooms	188,396
Bessemer ingots	114,120
Open-hearth ingots	142,301
Crucible steel ingots	604
Iron and steel in bars	176,377
Band iron and steel	70,347
Wire rods	23,140
Plates	15,441
Tubes and hollow blooms	22,827

* *Kommerskollegii underdaniga berättelse.* Stockholm, 1897.

Exports.—The Swedish statistics * of exports during the first half of this year show a falling off in comparison with the corresponding period of last year. The exports included 24,290 tons of pig iron, 65,810 tons of wrought iron, 1193 tons of sheets, 3376 tons of heavy castings, and 999 tons of nails.

There has been an enormous increase in the recent exports of iron ore from Luleå. In 1896 the quantity exported amounted to 625,795 tons † as compared with only 384,007 tons in 1895. Of the total quantity exported, 448,315 tons were for Germany. The United Kingdom came next with 91,400 tons, and then Belgium with 62,350 tons, and France with 21,550 tons.

Mineral Statistics of Norway.—For purposes of comparison the mineral statistics are given. The latest mineral statistics for that country which have been published relate to the year 1895. They include 1250 tons of iron ore, and 494 tons of nickel ore.

XIX.—SWITZERLAND.

Iron Trade Imports.—The value of the imports into Switzerland have been as follows in the years stated, † in millions of francs (1 million francs = £40,000):—

	1895.	1892.	1896.
Coal	17·6	33·2	46·7
Iron	14·5	24·9	35·7

The imports of machinery have been as follows:—

Machinery for	1892.	1896.
	Value, Francs.	Value, Francs.
Spinning	441,000	1,043,000
Weaving	191,000	310,000
Sewing	1,336,000	1,780,000
Tools	515,000	1,050,000
Dynamos	212,000	429,000
Electrical apparatus	791,000	1,975,000

* *Mining Journal*, vol. lxvii. p. 1176.

† *Deutsche Handels-Archiv*, August 1897.

‡ *Stahl und Eisen*, vol. xvii. p. 836.

XX.—UNITED STATES.

Iron Trade Statistics.—J. M. Swank * has submitted to the United States Department of the Interior an exhaustive report on the iron and steel industries.

The text of the Tariff Bill has been published,† with a comparison of the rates under the Gorman and M'Kinley bills.

The statistics published by the American Iron and Steel Association ‡ show that the total production of pig iron in the United States during the first half of 1897 amounted to 4,403,476 tons. Arranged according to the fuel used, the production was as follows:—

	Tons.
Anthracite	473,837
Charcoal	124,757
Bituminous	3,804,882

Iron Ore Production.—J. Birkinbine § gives the production of iron ore in the United States for 1896 as follows:—

	Tons.
Red hæmatite	12,576,288
Brown hæmatite	2,126,212
Magnetite	1,211,526
Carbonate	91,423
Total for 1896	16,005,449
Total for 1895	15,957,614

The ores came from twenty-three States, and the Lake Superior district supplied 10,566,359 tons of the total. The year's production was slightly greater in 1890, and about 290,000 tons higher in 1892, the year of maximum production. The ore is valued at the mines at an average of 5s. 11d. per ton, so that the total value for last year amounts to about £4,550,000. The largest producers are Michigan with 5·7 million tons, Minnesota with 4·28 million tons, and Alabama with 2·04 million tons, the other States all producing less than a million tons each.

Manganese Ore.—J. Birkinbine || reports that the production of manganese ore in the United States in 1896 was as follows:—

* *Eighteenth Annual Report of the United States Geological Survey.*

† *Iron Age*, vol. lx. No. 4, pp. 24-27.

‡ *Bulletin of the American Iron and Steel Association*, vol. xxi. No. 21.

§ *Eighteenth Annual Report of the United States Geological Survey.* || *Ibid.*

	Tons.
Virginia	2,018
Arkansas	3,421
Georgia	4,085
Other States	564
Total	10,088

Petroleum Production.—As regards the production of petroleum in 1896 in the United States, the principal features of the year are: the increase in production, which exceeds that of any previous year; a general increase in the Appalachian oil field, especially in West Virginia; a large increase of Lima oil in Ohio; an increase in stocks and a decrease in prices. The total production for the year is given as 60,960,361 barrels, an increase of 15·25 per cent. over that of 1895. Previously the largest production was in 1891, when about 54½ million barrels were obtained. The Appalachian field is accountable for 55·7 per cent. of the total, the Lima-Indiana field for 41·4, and the remaining fields have only yielded 2·9 per cent. *

The Bureau of Statistics reports that the exports of mineral oil from the United States during the half year ending June 30 amounted to 461,726,273 gallons.

Tin-Plates.—Colonel Ira Ayer † discusses the tin-plate industry in the United States. The industry dates its birth and the conditions which resulted in its rapid growth from the passage of the M'Kinley Tariff Act of October 1, 1890. The development of the industry is shown by the following statistics of production:—

	1892.	1896.
	Lbs.	Lbs.
Tin and terne plates	13,646,719	307,228,621
Amount made from—		
American black plates	9,296,553	303,002,098
Foreign black plates	4,350,166	4,226,523

Coal.—The twenty-second annual report of the Chief Inspector of Mines of Ohio shows that the coal production of the State in 1896 amounted to 12,912,608 tons, a decrease of 771,271 tons as compared with 1895. There were 303 accidents during the year, including 41

* *Eighteenth Annual Report of the United States Geological Survey.*

† *Journal of the Franklin Institute*, vol. cxliv. pp. 424-446.

fatal ones. There were 314,942 tons of coal mined to each life lost, 81,211 tons for each serious injury received, and 64,563 tons for each person injured.

The production of coal in the Indian Territory for the year ending June 30, 1897, was 1,302,378 tons, against 1,235,333 tons in the previous year. The total number of men employed was 3470, a total 225 less than in the previous year.

E. W. Parker has prepared for the United States Geological Survey some interesting statistics showing the development of the use of machines in the mining of coal in the United States during the past five years. The figures for 1896 and 1891 are as follows:—

	1891.	1896.
Number of tons mined by machines	2,739,743	12,533,522
Total tonnage mined	83,824,452	96,135,602
Percentage of total product mined by machine	3.27	13.06

The number of collieries using mechanical coal-cutters in 1896 was 115, the number of machines being 1139.

According to the official statistics, the production of coal in the United States in 1896 was 171,416,390 tons. This total includes 48,523,287 tons of Pennsylvania anthracite.

Mineral Statistics of California.—According to the statistics published by the California State Mining Bureau (Bulletin No. 12), the mineral production included 70,649 tons of coal, 1,257,780 barrels of petroleum, 318 tons of manganese ore, 786 tons of chrome ore, and 1500 tons of magnesite. The production of natural gas is valued at 111,457 dollars.

XXI.—COMPARATIVE TABLES.

The World's Production of Coal and Iron.—For the purposes of comparison, the following summary of the production of coal in the principal countries of the world is appended:—

Country.	Year.	Production in Tons.
United Kingdom	1896	195,361,260
Australia—		
New South Wales	1896	3,909,517
New Zealand	1895	740,827
Queensland	1896	377,350
South Australia	1896	862
Tasmania	1896	33,349
Victoria	1896	226,562
Western Australia	1896	9,801
Austria, coal	1895	9,722,679
lignite	1896	18,389,147
Hungary, coal	1895	1,068,046
lignite	1895	3,474,905
Belgium	1896	21,252,370
Borneo	1896	50,000
Canada	1896	3,395,807
Cape Colony	1896	107,050
France	1896	29,310,832
Germany, coal	1896	85,639,861
lignite	1896	26,797,880
Holland	1896	137,787
India	1896	3,848,013
Italy, lignite	1896	276,197
Japan	1896	3,000,000
Mexico	1896	253,104
Natal	1896	219,665
Peru	1892	2,000
Portugal, anthracite	1896	8,743
lignite	1896	8,000
Russia	1895	9,009,000
Servia	1894	120,000
South African Republic	1896	1,471,189
Spain	1896	1,852,947
Sweden	1896	225,848
United States	1896	171,416,390

A similar summary showing the production of pig iron is as follows :—

Country.	Year.	Production in Tons.
United Kingdom	1896	8,659,681
Austria	1895	778,510
Hungary	1895	349,163
Belgium	1896	959,414
Canada	1896	60,030
France	1896	2,333,702
Germany	1896	6,374,816
Italy	1895	9,213
Japan	1894	15,760
Russia	1895	1,454,298
Spain	1896	100,786
Sweden	1896	494,418
United States	1896	8,623,127

The Production of Mild Steel.—E. Schrödter * deals statistically with the present position and rise of the ingot iron manufacture, illustrating his statements by a number of tables and curves. At present by the Bessemer and open-hearth processes more than sixteen millions of tons of mild steel is produced annually, and in the form of a curve is shown the progress of the manufacture in the different countries of Europe and in the United States. The following table has reference to this, but in the author's paper details are given for each of the years 1865 to 1896.

Country.	1865.	1880.	1885.	1890.	1896.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
United Kingdom	225,000	1,320,561	2,020,450	3,637,381	4,200,000
United States	13,848	1,267,700	1,739,883	4,346,932	5,600,000
German Empire	99,543	624,418	893,742	1,613,783	3,437,981
France	40,574	388,894	553,839	581,998	883,508
Belgium	650	132,052	155,012	221,296	598,755
Austria-Hungary	3,879	134,218	278,783	499,600	868,834
Russia	3,871	295,568	192,895	378,424	...
Sweden	5,000	28,597	80,550	169,287	...
Italy . . . . .	...	...	6,370	107,676	...
Spain . . . . .	...	...	361	75,255	104,577

After dealing with the subject generally in this manner, the author proceeds to consider the progress of the industry in each country separately.

In the case of Germany the progress commences with the introduction of the basic process in the second half of the seventies. Up to that time there had been a limit to the possible production, but the new process rendered enormous deposits of iron ore available for steel manufacture, and the progress has been almost unbroken since that period. The author deals statistically with the production of rails, sheets, bar iron, and wire in Germany during each of the years previously referred to. The manufacture of Bessemer and open-hearth metal is then considered, and it is stated that, while in 1878 the number of workpeople employed in the manufacture of weld iron was 45,695, in 1895 this number had fallen to 38,190. In the case of ingot metal, on the other hand, the number of workpeople employed increased from 14,562 in 1878 to 75,080 in 1895.

The progress of the industry in the United States is next passed in review. The rapid progress of the open-hearth industry in the United

* *Stahl und Eisen*, vol. xvii. pp. 336-355.

States is shown by the fact that, while in 1886 the production of Bessemer steel amounted to 2,305,497 tons, and that of open-hearth steel to 224,477 tons, in 1894 these out-turns were respectively 3,628,454 tons and 797,495 tons, and in 1895, 4,987,674 tons and 1,155,377 tons. It is estimated that in 1896 the production of open-hearth steel amounted to as much as 1,600,000 tons, or seven times as much as it was ten years previously. The production of Bessemer metal in 1896 was 3,982,624 tons. In the case of 233 open-hearths for which details are available, ten took a 50-ton charge, six 40 tons, eight 35 tons, twenty-five 30 tons, twenty-four 25 tons, fifty 20 tons, two 18 tons, forty-five 15 tons, fourteen 12 tons, and twenty-five 10 tons. Eighty per cent. of the total quantity of open-hearth metal made in the United States is produced in Pennsylvania. Other details relating to the production of rails, &c., are also given.

Turning next to the United Kingdom, the author gives statistics for the same period dealt with in the case of the other countries—1865 to 1896. The falling off in the manufacture of puddled iron is, he shows, extremely marked. In 1877 the number of existing puddling furnaces was 7159, whilst in 1895 only 3095 furnaces were in existence, and of these but 1775 were in operation. The production of Bessemer metal increased rapidly up to 1889, but since then there has been a diminution.

In 1896, 25·1 per cent. of the total production of Bessemer metal was made in basic-lined converters. Of the 101 existing converters in 1896, 23 were basic lined. In 1873, the out-turn of open-hearth metal was only 77,500 tons, but the increase in the production was subsequently so rapid, that in 1894 it exceeded the Bessemer out-turn; and in 1896, of the total ingots made, only 43·9 was made by the Bessemer process, whilst as much as 56·1 was made in the open-hearth. The basic open-hearth process, it is pointed out, is still relatively unimportant in the United Kingdom.

France is next dealt with briefly, and similar statistics are also given for this country, and also for the other countries previously mentioned. The author then proceeds to a general consideration of the state of the iron trade, and, dealing with the dephosphorisation process, he gives statistics showing the rise of this process in each country. No complete details are procurable since 1892, still such details as are obtainable show how rapid the progress has been. Thus in 1878 only 20 tons was made by this process, whilst in 1893, 3,638,556 tons was made, including the production in Belgium and in the United States, for

which details are not given. The cause of this relative degree of importance which the basic process has attained in each of the different countries is then considered, and whilst both in the United States and in the United Kingdom it has as yet attained little importance, this is shown to be due to entirely different causes.

Development of the World's Iron Trade.—Bennett H. Brough * states that since 1870 the world's production of pig iron has increased from 12,000,000 to 30,000,000 tons; but during that time, whilst the United States, Germany, Russia, and Austria-Hungary have gained ground, Great Britain, France, Belgium, and Sweden have lost ground. The total production of pig iron from 1870 to 1896 inclusive was as follows:—

Country.	Millions of Tons.	Per Cent.
Great Britain	198.3	37.0
United States	134.0	25.0
Germany and Luxemburg	91.8	17.2
France	45.3	8.5
Austria-Hungary	18.5	3.5
Belgium	18.2	3.4
Russia	17.8	3.3
Sweden	11.0	2.1
Total	534.9	100.0

The production of each country at the beginning and end of the period under consideration was as follows:—

Country.	1870. Millions of Tons.	1896. Millions of Tons.
Great Britain	6.0	8.6
United States	1.7	8.6
Germany and Luxemburg	1.4	6.4
France	1.2	2.3
Russia	0.4	1.5
Austria-Hungary	0.3	1.0
Belgium	0.6	0.9
Sweden	0.3	0.5
Total	11.9	29.8

The pig iron production in Great Britain and in the United States last year was practically the same, the official figures being 8,659,681 tons for the former and 8,623,127 tons for the latter.

* *Journal of the Society of Arts*, vol. xli. p. 76.

The share taken by each country was as follows :—

Country.	1870. Per Cent.	1896. Per Cent.
Great Britain	50.5	29.0
United States	14.3	29.0
Germany and Luxemburg	11.8	21.5
France	10.1	7.7
Russia	3.3	5.0
Austria-Hungary	2.5	3.2
Belgium	5.0	3.0
Sweden	2.5	1.6
Total	100.0	100.0

The Fuel Supply of the World.—In the Mathematical Section of the British Association, Lord Kelvin gave an address on the fuel supply and air supply of the world. He quoted valuable statistics concerning the coal supply of the United Kingdom and its relation to the amount of oxygen in the atmosphere. The chief point of the address was that the amount of oxygen in the air was barely sufficient to consume the available fuel, and that mankind was more likely to suffer in time from lack of the former than of the latter. The chief necessity, therefore, was to see that by vegetation the supply of oxygen was constantly and adequately renewed. In the course of his address, Lord Kelvin incidentally expressed the belief that life had existed on the earth for twenty million years.

Mine Accidents.—According to *Glückauf*,* the average annual number of fatal accidents in the years 1891 to 1895 per 1000 men employed in collieries was as follows :—

Country.	Total.	From Falls of Roof and Sides.
France	1.099	0.400
Belgium	1.664	0.544
Great Britain	1.536	0.645
Prussia	2.493	0.921

The World's Railways.—In the five years 1891–95, the length of the world's railways has increased by 62,465 kilometres (say 38,800 miles), an increase of 9.8 per cent. Of this increase only 22,104 kilometres was in Europe.† The total length of all the railways at the

* Vol. xxxiii. p. 707.

† *Stahl und Eisen*, vol. xvii. pp. 543–545.

end of 1895 amounted to 698,356 kilometres—approximately 434,000 miles. This total was made up as follows :—

	Kilometres.
America	369,686
Europe	249,899
Asia	43,279
Australia	22,349
Africa	13,143
Total	698,356

Full details are given for each country and for each of the years 1891–95. The following are some of these :—

	Length in Kilometres.	
	1891.	1895.
United Kingdom	32,487	33,648
Austria-Hungary	28,066	30,046
France	37,723	40,199
Germany	43,424	46,413
Russia	31,071	37,746

Bennett H. Brough * states that although there were in Sweden, in 1856, not more than forty-one miles of railways for locomotives, at the present time no other country in Europe has so great a length of railway per inhabitant. This is shown in the following table, which, on the authority of the *Journal Officiel* of October 28, 1897, gives the number of miles of railway per 10,000 inhabitants on January 1, 1897 :—

	Miles.
Sweden	12·5
Switzerland	7·4
France	6·6
Denmark	6·1
Norway	6·0
Germany	5·6
Belgium	5·6
United Kingdom	5·4
Austria-Hungary	4·5
Spain	4·2
Holland and Luxemburg	3·8
Roumania	3·3
Italy	3·0
Portugal	2·8
Greece	2·7
Russia	2·3
Servia	2·3
Turkey	1·7

At the present time Sweden possesses 6154 miles of railway.

* *Journal of the Society of Arts*, vol. xlv. p. 63

BIBLIOGRAPHY.

The following is a list of the principal works relating to iron and steel published during the second half of 1897:—

METALLURGY.

- BECK, L. "*Die Geschichte des Eisens.*" Vol. IV. Part I. 8vo, pp. 176. Brunswick: F. Vieweg. (Price 5s.)
- BECKERT, T. "*Kerpely's Bericht über die Fortschritte des Eisenhütten Technik im Jahre 1893.*" 8vo, pp. 362. Leipzig. (Price 22s.)
- BERTHELOT, M. "*Thermochemie et Lois Numeriques.*" 2 vols. 8vo, pp. 773 and 878. Paris: Gauthier Villars.
- BORCHERS, W. "*Electric Smelting and Refining.*" Translated by W. G. McMillan. 8vo. London: C. Griffin. (Price 21s.)
- CHÔMIENNE, C. "*Fabrication de l'acier et procédés de forgeage de diverses pièces.*" 8vo, pp. 228, with 33 plates. Paris: E. Bernard. (Price 10 francs.)
- DÜRRE, E. F. "*Vorlesungen über Allgemeine Hüttenkunde.*" Part I. 4to, pp. 128. Halle: W. Knapp. (Price 10s.)
- FRITZSCHE, P. "*Die Untersuchung und Bewerthung der Brennstoffe.*" 8vo, pp. 128, with 23 figures and 15 tables. Leipzig: Quant & Händel. (Price 3s. 9d.)
- GABBA, L. "*Raccolta di tabelle di dati fisici e chimici e di processi d'analisi tecnica.*" 8vo, pp. 442. Milan.
- GHERSI, J. "*Leghi metalliche ed amalgame.*" 8vo, pp. 431, with 15 illustrations. Milan.
- GILL, A. H. "*Gas and Fuel Analysis for Beginners.*" 8vo, pp. 90. New York: J. Wiley. (Price 1.25 dollar.)
- HEINZERLING, F., and O. INTZE. "*Deutsches Normalprofilbuch für Walzisen zu Bau- und Schiffbauzwecken.*" 5th edition. Aix-la-Chapelle: J. La Ruelle. (Price 10s.)
- HOYER, E. VON. "*Die Verarbeitung der Metalle.*" 3rd edition. 8vo, pp. 515, with 421 figures. Wiesbaden: C. W. Kreidel. (Price 12s.)
- LAHARPE, C. DE. "*Notes et Formules de l'Ingénieur.*" 11th edition. pp. 1312, with 1000 illustrations. Paris: E. Bernard. (Price 10 francs.)
- MOISSAN, H. "*La Four Electrique.*" 8vo, pp. 385. Paris: G. Steinheil.

- ROBERTS-AUSTEN, W. C. "*Introduction to the Study of Metallurgy.*" 4th edition. London: C. Griffin. (Price 12s. 6d.)
- SIEVERS. "*Karte der Berg- und Hüttenwerke im Oberbergamtsbezirk Dortmund.*" 8th edition. Leipzig: J. Baedeker. (Price 3s.)
- TOLDT, F. "*Die Chemie des Eisens.*" Leoben: L. Nüssler. (Price 3s.)
- TOLDT, F. "*Über das Trocknen von Thon.*" 8vo, pp. 16. Leoben: L. Nüssler.
- VENATOR, M. "*English—German—Spanish—French Dictionary of the Terms employed in Mining, Metallurgy, and Chemistry.*" Leipzig: A. Twietmeyer.
- WEDDING, H. "*Ausführliches Handbuch der Eisenhüttenkunde.*" Vol. II. Part I. 8vo, pp. 274, illustrated. Brunswick: F. Vieweg. (Price 10s.)
- WEST, T. D. "*Metallurgy of Cast Iron.*" 8vo, pp. 583, with 107 illustrations. London: E. & F. N. Spon. (Price 12s. 6d.)

MINING.

- ANDERSON, J. W. "*Prospector's Handbook.*" 7th edition. London: Crosby Lockwood. (Price 3s. 6d.)
- BILHARZ, O. "*Die mechanische Aufbereitung von Erzen und mineralischen Kohlen.*" Vol. I. (Price 34s.) Vol. II. (Price 22s.) Leipzig.
- BROUGH, BENNETT H. "*A Treatise on Mine-Surveying.*" 6th edition. London: C. Griffin. (Price 7s. 6d.)
- CAMBESSÉDÈS, F. "*Note sur l'exploitation des veines minces du bassin Franco-Belge.*" St. Etienne: Theolier et Cie.
- DRÖGE, A. "*Die Einrichtungen zur unschädlichmachung des Kohlenstaubes.*" 8vo, pp. 40, with 3 plates. Berlin: W. Ernst. (Price 5s.)
- FISCHER, F. "*Die chemische Technologie der Brennstoffe.*" Brunswick. (Price 18s.)
- GOUPILLIÈRE, HATON DE LA. "*Cours d'exploitation des mines.*" 2nd edition, vol. ii. pp. 1069, illustrated. Paris: P. Vicq-Dunod. (Price 35 francs.)
- GRUNER, A. "*Atlas du Comité Central des Houillères de France.*" 4to, pp. 76, with 36 plates. Paris.
- HARTMANN, K., and J. O. KNOKE. "*Die Pumpen.*" 2nd edition. 8vo, pp. 675, with 664 illustrations and 6 plates. Berlin: J. Springer. (Price 16s.)
- HEUSLER, C. "*Beschreibung des Bergreviers Brühl-Unkel.*" 8vo, pp. 239. Bonn. (Price 7s. 6d.)
- HÖFER, H. "*Taschenbuch für Bergmänner.*" Leoben. (Price 12s. 6d.)
- HOWARD, F. T., and E. W. SMALL. "*Set of Twelve Diagrams Illustrating the Principles of Mining.*" London: Chapman & Hall. (Price 21s.)

- HULL, E. "*Our Coal Resources at the Close of the Nineteenth Century.*" 8vo, pp. 157. London: Spon.
- KLEIN, W. "*Oesterreichisch-ungarischer Berg- und Hütten Kalender pro 1898.*" 23rd year. Vienna: M. Perles. (Price 3s.)
- KOEHLER, G. "*Lehrbuch der Bergbaukunde.*" 4th edition. 8vo, pp. 791, with 706 illustrations and 7 plates. Leipzig: W. Engelmann. (Price 17s.)
- LAWN, J. G. "*Mine Accounts and Mining Book-Keeping.*" 8vo. London: C. Griffin. (Price 10s. 6d.)
- MCCALLEY, H. "*Report on the Valley Regions of Alabama.*"
- MACSWINNEY, R. F. "*Law of Mines, Quarries, and Minerals.*" 8vo. London: Sweet & Maxwell. (Price 40s.)
- MERIVALE, J. H. "*Notes and Formulæ for Mining Students.*" 4th edition. London: Crosby Lockwood. (Price 2s. 6d.)
- MIRON, F. "*Les huiles minérales.*" 8vo, pp. 198. Paris. (Price 2½ francs.)
- NICOLLS, W. J. "*Story of American Coals.*" London. (Price 18s.)
- ORIOI, R. "*Anuario de la minería de España.*" Madrid. (Price 10 francs.)
- PERCY, C. M. "*Mining in the Victorian Era.*" 8vo, pp. 93. Wigan: Wall & Sons. (Price 1s.)
- PERKIN, H. "*Practical Coal-Mining.*" Leeds: Reynolds & Branson. (Price 1s.)
- ROTHWEL, R. P. "*The Mineral Industry.*" 8vo, pp. 865. New York: The Scientific Publishing Company. (Price £1, 0s. 10d.)
- SIMMERSBACH, O. "*Die Koksfeuerung als Lösung der Rauchfrage.*" 8vo. Gelsenkirchen.
- WATTS, W. L. "*Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara Counties.*" 8vo, pp. 94. Sacramento.
- WILLIAMSON, W. "*Mining Examination Questions.*" 6th edition. Hamilton: W. Naismith.

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